# ACRP
## Research Report 220

**Airport Cooperative Research Program**
Sponsored by the Federal Aviation Administration

# Guidebook for Developing a Zero- or Low-Emissions Roadmap at Airports

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP RESEARCH REPORT 220

# Guidebook for Developing a Zero- or Low-Emissions Roadmap at Airports


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## AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). ACRP carries out applied research on problems that are shared by airport operating agencies and not being adequately addressed by existing federal research programs. ACRP is modeled after the successful National Cooperative Highway Research Program (NCHRP) and Transit Cooperative Research Program (TCRP). ACRP undertakes research and other technical activities in various airport subject areas, including design, construction, legal, maintenance, operations, safety, policy, planning, human resources, and administration. ACRP provides a forum where airport operators can cooperatively address common operational problems.

ACRP was authorized in December 2003 as part of the Vision 100—Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), Airlines for America (A4A), and the Airport Consultants Council (ACC) as vital links to the airport community; (2) TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academy of Sciences formally initiating the program.

ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

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Once selected, each ACRP project is assigned to an expert panel appointed by TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended users of the research: airport operating agencies, service providers, and academic institutions. ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties; industry associations may arrange for workshops, training aids, field visits, webinars, and other activities to ensure that results are implemented by airport industry practitioners.

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# FOREWORD

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To reduce or eliminate carbon emissions at airports requires long planning horizons and airports can benefit from understanding where they should start. *ACRP Research Report 220: Guidebook for Developing a Zero- or Low-Emissions Roadmap at Airports* provides the resources and processes to begin. The guidebook includes tools, resources, and information that airport staff can use as they begin considering options to reduce carbon emissions. This guidebook was further enhanced with information and lessons learned from piloting the implementation at two airports—a large-hub and small-hub airport.

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As global initiatives toward the objective of reducing or eliminating carbon emissions continue to grow, technologies designed to do so have also grown and become more financially feasible. The investment in infrastructure and new technologies to support that objective needs time to plan and there isn't one solution, but many different initiatives will need to be employed. Developing a roadmap allows an airport to identify its policies and technologies in advance of their need so that they can plan and budget accordingly.

The Cadmus Group was selected to develop this guidance and a methodology for airports to develop a roadmap to achieve zero or low emissions. Their research included interviews at 12 different airports from around the world, and eight other organizations on their initiatives towards zero or low emissions. They validated their findings and conducted a pilot implementation at a large-hub and small-hub airport. The guide was updated to reflect the lessons learned. Appendix E provides more information about the pilots.

This guidance will be useful to airport staff of all sizes of airports and to those who work in administration, planning, and sustainability. This guidance helps bring together all of the necessary stakeholders to help develop a roadmap for zero or low emissions.

# CONTENTS

Note: Photographs, figures, and tables in this report may have been converted from color to grayscale for printing. The electronic version of the report (posted on the web at www.trb.org) retains the color versions.

SUMMARY

# Guidebook for Developing a Zero- or Low-Emissions Roadmap at Airports

## Objective of Guidebook

*ACRP Research Report 220: Guidebook for Developing a Zero- or Low-Emissions Roadmap at Airports* provides airports with the information and resources needed to create a zero- or low-emissions roadmap.[1] The guidebook covers all steps of roadmap development, from start to finish, using conceptual diagrams, examples, best practices, and links to external tools and resources. While the main focus of this guidebook is airport-controlled greenhouse gas (GHG) emissions, the guidebook also discusses airport-influenced emissions from airlines, concessionaires, passengers, and other third parties. Throughout the guidebook, reductions in local air pollution are discussed as co-benefits.

Whereas other guidebooks and reference material provide airports with information on emissions mitigation and management—FAA's *Airport Carbon Emissions Reduction* (2019a); *ACRP Report 11: Guidebook on Preparing Airport Greenhouse Gas Emissions Inventories* (Kim et al. 2009); ACI's *Guidance Manual: Airport Greenhouse Gas Emissions Management* (2009)—this guidebook articulates steps for creating an *airport-specific emissions roadmap.*

Examples of questions addressed by this guidebook include:

- How can airports make a business case to pursue zero- or low-emissions targets? [Chapter 1]
- How can airports catalyze internal and external stakeholders into developing zero emissions goals or targets? [Chapter 2]
- How should airports set goals and target years en route to zero- or low-emissions targets? [Chapter 3]
- How should airports evaluate the technology-fuel mixes needed to achieve a given emissions target? [Chapter 4]
- What are examples of innovative airport programs that can achieve deep emissions reductions? [Chapters 2 to 4]
- What are the pros and cons of various funding options for emissions reductions? [Chapter 5]
- How can airports effectively monitor their emissions reduction programs? [Chapter 6]

Even if an airport is not ready to develop a full emissions roadmap, the guidebook may still be useful. The guidebook is written in a scalable fashion, so that users can pick-and-choose strategies and contents that suit their needs. Airports should focus on near-term, cost-effective strategies to build momentum over time. With enough successes, an airport may be ready to develop an emissions roadmap.

[1] While noise can be considered an "emission" as well, only air quality and GHG emissions are within the scope of this guidebook.

## Audience for Guidebook

This guidebook is intended primarily for airports of all sizes and in all global regions, including small-, medium-, and large-hub commercial service, reliever, and general aviation, that are interested in developing a zero- or low-emissions roadmap. Even airports without deep interest in long-term emission reductions can benefit from the contents of the guidebook. The target audience for this guidebook includes:

- **Airport administrators and decision makers.** The guidebook provides the information necessary to pursue zero- or low-emissions targets and to consider the impact of these targets within the broader goals of the airport and associated stakeholders.
- **Airport financial staff.** The guidebook provides those responsible for the financial and budgetary aspects of airport projects, operations, and maintenance with the information required to evaluate the costs and benefits of a zero- or low-emissions initiative including required long-term investment needs.
- **Airport technical staff including airport engineers and sustainability personnel.** The guidebook assists technical personnel with evaluating infrastructure projects, building efficiencies, and implementing operational changes that ensure long-term sustainability and cost-effectiveness of airport operations while also promoting the airport's stated emissions reduction goals.

## Role of Roadmaps

Airports worldwide are setting aggressive zero- or low-emissions targets. To meet these targets, airports are deploying new strategies, adopting innovative financing mechanisms, and harnessing the collective resources of voluntary emissions and reporting programs like Airport Carbon Accreditation (ACA), Science-Based Targets (SBTs), The Climate Registry (TCR), Global Reporting Initiative (GRI), and others. In tandem, new and affordable zero- or low-emissions technologies are rapidly becoming available at airports. Vehicle fleet electrification is now possible and economically attractive for a wide variety of vehicle types. Energy-efficient buildings, facilities, and end uses are providing short paybacks and high return on investment. Renewable resources such as solar, wind, and geothermal are often the lowest-cost electricity option for airports.

The investments needed to support zero- or low-emission technologies at airports often require long planning horizons and close coordination between many stakeholders. A roadmap is an effective tool for fulfilling these needs and signaling to the broader set of airport investors and partners that an airport takes climate change seriously. This signal has real financial benefits, as discussed in Chapter 1.3.

### Global Trend

Setting aggressive emission reduction targets at airports is part of a broader global trend. Eight countries and one province have pledged to eliminate economy-wide emissions in the coming decades, while other countries and cities have announced plans to eliminate emissions in specific sectors or to establish "low-emission zones." A growing number of cities (such as C40 Cities), universities, and businesses have also announced carbon neutrality targets for 2050.

## Development of Guidebook

This guidebook is the culmination of work conducted between 2018 and 2021. Key tasks during the development of the guidebook included a detailed literature review; interviews with approximately 20 U.S.-based and international airports; 3 day-long workshops with pilot airports (Detroit Metropolitan Wayne County Airport, Portland-Hillsboro

Airport, and John Wayne Airport); and an in-depth year-long implementation project with two airports (Detroit Metropolitan Wayne County Airport and Eugene Airport). A detailed description of the year-long implementation project is provided in Appendix E.

## Organization of Guidebook

This guidebook is organized into six overarching chapters that correspond to the steps needed to create an airport-specific roadmap to a zero- or low-emissions target.

- **Chapter 1** lays out the basic knowledge and concepts to begin the roadmapping process, describes how to create a compelling business case, and provides important context.
- **Chapter 2** describes effective engagement strategies that encourage buy-in for the roadmap from internal and external stakeholders.
- **Chapter 3** reviews steps for setting goals, baselines, and targets.
- **Chapter 4** describes emissions reduction strategies.
- **Chapter 5** discusses funding opportunities and mechanisms.
- **Chapter 6** reviews key steps for monitoring, outreach, and reporting.

The appendices provide a glossary of terms, frequently asked questions, example graphics for zero- or low-emissions roadmaps, and a chapter on the implementation of the guidebook.

### How to Use this Guidebook

The diagram on the following page depicts a step-by-step process for creating an airport-specific roadmap. All steps in the diagram should be considered iterative—each are linked and should be re-visited periodically.


**CHAPTER 1**
INITIATION OF THE ROADMAP

**Section 1.1:** Ensure Understanding of Foundational Concepts

**Section 1.2:** Review Emission Reduction Programs, Policies, and Regulations

**Section 1.3:** Build Business Cases for Zero- or Low-Emissions Planning Programs

**Section 1.4:** Establish Roadmap Management and Governance

**CHAPTER 2** STAKEHOLDER ENGAGEMENT

**Section 2.1:** Create Stakeholder Teams

**Section 2.2:** Conduct Ongoing Stakeholder Communication

**CHAPTER 3**
SETTING EMISSIONS GOALS, BASELINES, AND TARGETS

**Section 3.1:** Conduct GHG Inventory

**Section 3.2:** Define Goal Boundary

**Section 3.3:** Choose Goal Type

**Section 3.4:** Define Target Years

**Section 3.5:** Define Allowable Emissions in Target Years

**CHAPTER 4**
EMISSIONS REDUCTION STRATEGIES

**Section 4.1:** Reduce Scope 1 and Scope 2 Emissions

**Section 4.2:** Offset Emissions

**Section 4.3:** Reduce Scope 3 Emissions

**Section 4.4:** Select Strategies

**CHAPTER 5**
FUNDING OPPORTUNITIES AND MECHANISMS

**Section 5.1:** Public Funding

**Section 5.2:** Airport-Based Funding

**Section 5.3:** Third-Party Funding

**CHAPTER 6**
MONITORING AND OUTREACH

**Section 6.1:** Develop Monitoring and Reporting Program

**Section 6.2:** Identify Triggers for Re-Evaluation

**Section 6.3:** Conduct Outreach

CHAPTER 1

# Initiation of the Roadmap

This guidebook provides steps to assist airports with developing an airport-specific zero- or low-emission roadmap. This chapter provides information and steps needed to initiate the roadmapping process, shown in Figure 1. The steps in this chapter should be performed iteratively and in coordination with the steps outlined in other chapters.

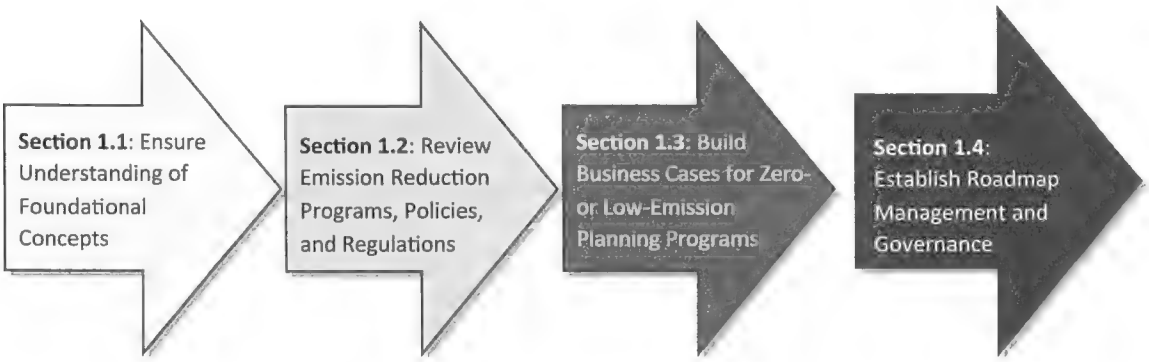


*Figure 1. Steps to initiate roadmap planning.*

## 1.1 Ensure Understanding of Foundational Concepts

Beginning the roadmapping process requires an understanding of the building blocks of emissions reductions at airports. This chapter provides an introduction to the core concepts that ensure a baseline level of understanding. Airport staff, who are new to airport emissions, should read this chapter in its entirety.

### What is a Zero- or Low-Emissions Roadmap?

Although definitions may vary by airport, all zero- or low-emissions roadmaps should include several concepts:

- **Target-oriented.** Emissions roadmaps should include a commitment to limit greenhouse gas (GHG) emissions to a specified quantity by a specified date.
- **Sequential.** Emissions roadmaps should provide the major steps or milestones needed to reach the emissions target.
- **Stakeholder-informed.** Internal and external stakeholders should be involved in both developing and maintaining the emissions roadmap.
- **Assisted by visuals.** Roadmaps typically have a heavy visual component including infographics, diagrams, conceptual figures, and qualitative tables. This focus on visual aspects helps ensure that the document is accessible to a wide audience over a long time period.

A zero- or low-emissions roadmap can be a single page or many pages. Similarly, a roadmap can be a stand-alone document or part of a broader environmental or sustainability plan, such as a sustainability management plan. The word "roadmap" is often used interchangeably with "blueprint," "action plan," or simply "plan."

## Sources of Emissions at Airports

In most airport settings, airport operators typically have direct control over 20% or less (usually much less) of an airport's total GHG emissions, while airlines, caterers, cargo handlers, retailers, freight companies, and passengers are responsible for the large majority. To help standardize boundaries and emissions reporting, most airports use the three "scopes" (Scope 1, Scope 2, and Scope 3) defined by the Greenhouse Gas Protocol (WBCSD and WRI 2015), an internationally recognized standard for quantifying and tracking GHG (see Figure 2).

- **Scope 1.** Airport operator emissions associated with vehicles and ground support equipment belonging to the airport, on-site waste management, on-site wastewater management, and on-site power generation, firefighting exercises, boilers, and furnaces.
- **Scope 2.** Indirect emissions from off-site purchased electricity and steam.
- **Scope 3.** Indirect emissions as a consequence of airport activities including aircraft landing and take-off (under 3,000 feet), aircraft ground movements, auxiliary power units, third-party vehicles, ground support equipment, passenger travel to and from the airport, staff commute, off-site waste management, off-site water management, and staff business travel.

Other related concepts in airport emissions planning are "ownership" and "influence," which are discussed in detail in *ACRP Report 11* (Kim et al. 2009), *ACRP Report 56: Handbook for Considering Practical Greenhouse Gas Emission Reduction Strategies for Airports* (CMD 2011), and *ACRP Synthesis 100: Airport Greenhouse Gas Reduction Efforts* (Barrett 2019). Ownership means that an entity has the decision-making power to determine if and how an emissions source should be reduced. Influence means that an entity has a linkage to the emissions source but no direct decision-making power over whether those emissions are released.

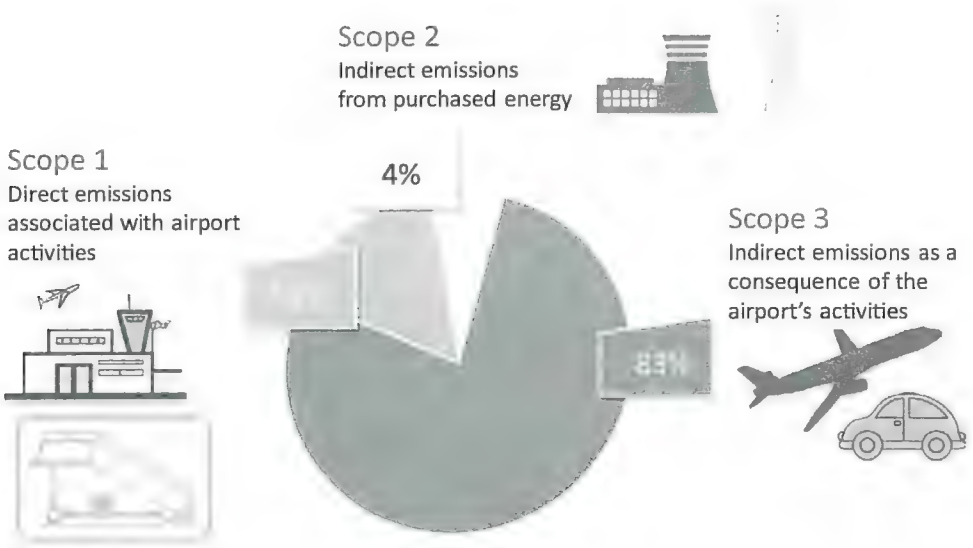


***Figure 2. Average airport emissions, by scope.***

There are three entities in the airport context that own or influence emissions:

- Airport operators,
- Tenants (primarily airlines, concessionaires, and aircraft operators), and
- General public.

Table 1 gives examples of emissions sources by scope, type, and ownership versus influence category. Scope 1 and Scope 2 emissions at an airport are *owned* by the airport operator, while Scope 3 emissions are *owned* by tenants and the general public but *influenced* by the airport operator. Since Scope 3 emissions are not airport controlled, they are generally the most difficult for an airport operator to reduce directly (*ACRP Report 11* and *ACRP Report 56*). This guidebook provides information about Scope 3 emissions in Section 4.3, but the focus is on Scope 1 and Scope 2 emissions.

### GHG Accounting

Several complex situations arise when defining the boundaries of emission scopes. These situations include airports leasing vehicles from a private company, airports providing tenants with electricity, and airports providing infrastructure to tenants. These situations are a factor not only for GHG emission inventories, but also for developing emission mitigation strategies. Since emission scopes are not a central focus of this guidebook, these boundary questions are addressed more in Appendix B.

## Terminology

Several terms are often used interchangeability when referring to emissions goals. Using terminology that is consistent with the broader environmental community helps avoid confusion and facilitates communication regarding an airport's emissions reduction goal. Table 2 defines the recommended terms to be used in airport emission roadmaps.

**Table 1. Greenhouse gas emissions sources by level of airport control.**

| Category | Emissions Sources | Scope 1 | Scope 2 | Scope 3 |
|---|---|---|---|---|
| | | Ownership | | Influence |
| Electricity | On-site electricity production | x | | |
| | Purchased grid electricity | | x | |
| | Electricity consumed by tenants, partners, subcontractors, grid power, and other third parties | | | x |
| Stationary Sources | Airport-owned or airport-leased boilers, furnaces, burners, turbines, heaters, incinerators, engines, firefighting exercises, flares, generators, and other | x | | |
| | Tenant-owned or tenant-leased boilers, furnaces, burners, turbines, heaters, incinerators, engines, firefighting exercises, flares, generators, and other | | | x |
| Vehicle Travel | Airport-owned or operated shuttle buses, maintenance vehicles, security vehicles, and emergency vehicles | x | | |
| | Airport staff business travel | | | x |
| | Tenant-controlled vehicles, such as ground support equipment, passenger ground transportation, third-party owned vehicles, and other | | | x |
| | Airport staff commute | | | x |
| | Passenger private vehicles | | | x |
| Waste Management | On-site waste management, wastewater management, and other | x | | |
| | Off-site waste management by third-party operators | | | x |
| Aircraft | Aircraft ground movements, taxiing, auxiliary power units (APUs), pre-conditioned air units (PCAs), and landing and take-off | | | x |
| Other | Leaks from fire suppression activities, refrigerants, and construction emissions | x | | |

**Table 2. Terms used to describe emissions goals.**

| | Term | Definition | Includes use of offsets? | Synonyms |
|---|---|---|---|---|
| Less Costly or Complex | Zero Carbon Growth | A condition in which Scope 1 and Scope 2 emissions do not grow larger each year. | Yes | • Carbon Neutral Growth |
| | Carbon Neutral | The sum of Scope 1 and Scope 2 emissions and sinks (including offsets) is zero. | Yes | • Climate Neutral<br>• Net Zero<br>• Zero Carbon Footprint |
| | Carbon Negative | The sum of Scope 1 and Scope 2 emissions and sinks (including offsets) is negative. | Yes | • Climate Positive<br>• Net Carbon Negative |
| More Costly or Complex | Carbon Free | 100% of Scope 1 and Scope 2 emission sources are from renewable sources. This condition can only be met when all end uses are electrified or use zero- or negative-emissions synthetic fuels. | No | • Zero Emissions<br>• Zero Carbon<br>• 100% Renewable |

Although the terms in Table 2 imply a shared underlying goal of reducing GHG emissions, there are important differences in the level of planning, commitment, and expenditures needed to achieve these levels. For example, zero carbon growth requires stabilizing $CO_2$ emissions, so they do not grow over time, whereas a carbon free status requires full electrification of all end uses and conversion to 100% renewable electricity.

## 1.2 Review Emission Reduction Programs, Policies, and Regulations

This section describes major emission reduction programs, policies, and regulations that may impact development of an emissions roadmap. In addition to the brief description below, guidebook users are encouraged to examine the local and regional regulations in their area.

### Voluntary Emissions Reporting and Reduction Programs

In 2009, the trade association Airport Council International-Europe launched the Airport Carbon Accreditation (ACA) program at its annual assembly. ACA is a carbon emissions reporting and management program designed specifically for airports and is supported by an advisory board comprising international climate and aviation experts. Today, ACA is administered by the firm WSP and is a leading voluntary emissions program in the global airport community. Figure 3 highlights the growing number of participating airports in the ACA program through mid-2018.

ACA includes six levels of carbon certification, with Levels 4 and 4+ added in 2020 (as shown in the box). The ACA program is considering developing an additional level in the future to recognize airports that achieve zero carbon emissions without the use of offsets (timing of the additional level is uncertain). In the United States, 31 airports are accredited under ACA, with Dallas Fort Worth (DFW) the only airport to achieve the highest accreditation level, *Level 4+* (Transition). San Diego International Airport (SAN) has achieved Level 3+ (*Neutrality*), and San Francisco International Airport (SFO) has also signaled a strong interest in achieving Level 3+ in the near term (SFO 2018).

Additional carbon neutrality programs and pledges for airports have also emerged in recent years. For example, at the Paris Climate Conference of Parties 21 (COP21) Climate Summit,

**Summary of ACA Levels**

1. **Level 1 (Mapping):** This level includes determining the emissions sources within the operational boundary of the airport, reporting annually, and compiling a carbon footprint report.
2. **Level 2 (Reduction):** At this level, airports must provide evidence of having achieved reduction targets.
3. **Level 3 (Optimization):** At this level, airports must include Scope 3 emissions in their carbon reporting and engage third-party operators about emissions reduction.
4. **Level 3+ (Neutrality):** At this level, airports also offset remaining Scope 1 and Scope 2 emissions with "high quality" carbon credits.
5. **Level 4 (Transformation):** At this level, airports must meet requirements of Level 3+, plus adoption of a long-term carbon reduction strategy aligned with the Paris Agreement. This level also requires action to drive carbon reductions by third parties.
6. **Level 4+ (Transition):** This level requires all requirements from the prior levels plus offsetting the residual Scope 1 and 2 carbon emissions using "internationally recognized" carbon offsets.

50 European airports pledged to be carbon neutral by 2030. Additionally, the Massachusetts Department of Transportation (MassDOT) established the Carbon Neutral Airport program and sought to achieve zero emissions at Nantucket Memorial Airport. Similarly, Appleton International Airport—supported by the FAA Sustainable Master Plan Pilot Program—has set a goal of being carbon neutral by 2030 (ATW 2019).

The Climate Registry (TCR) is another organization that promotes voluntary emissions reporting and reduction efforts. TCR is a nonprofit organization governed by U.S. states and Canadian provinces and territories to encourage organizations in North America to reduce their emissions by helping them measure, report, and confirm their carbon footprints. TCR is

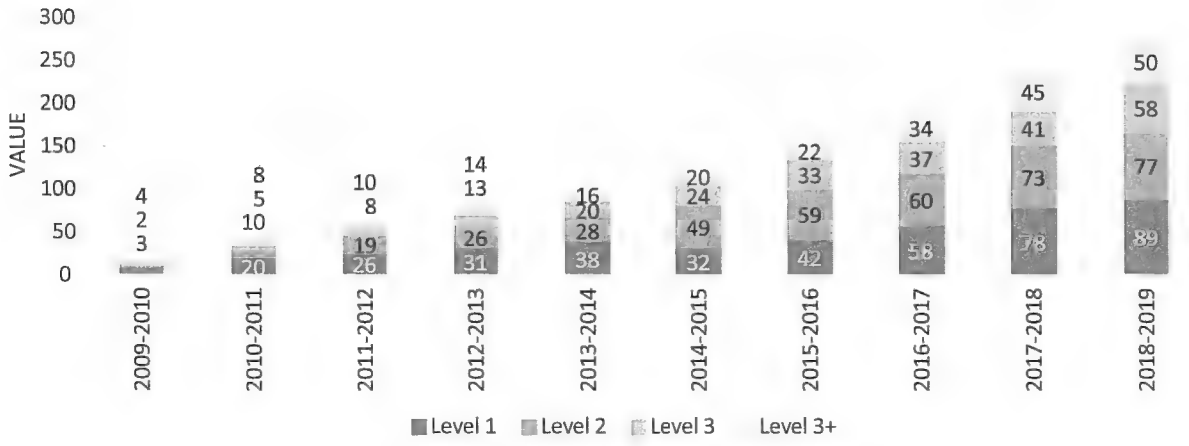


***Figure 3. Growth in airports accredited under ACA (developed using ACA annual reports). Note: Level 4 and 4+ are not shown because they were not in latest ACA annual report.***

**Summary of CFR Levels**

1. **Bronze:** Joined TCR for purposes of capacity building, but not yet reporting emissions. Complete at least two TCR trainings.
2. **Silver:** Report GHG emissions within a self-defined boundary, complete at least two trainings.
3. **Gold:** Report and verify GHG emissions within a self-defined boundary, complete at least two trainings, and at least two of the following: generate or purchase renewable energy and retain the credits, develop and verify a TCR approved performance metric, and/or set a public base year.
4. **Platinum:** Report GHGs according to TCR's criteria for complete reporting, set public baseline year, develop GHG reduction goal and at least two of the following: trainings, generate or purchase renewable energy and retain the credits, develop and verify a TCR recognized performance metric.
5. **Allstar:** All of the requirements for Platinum plus disclosure of a third-party verified public base year inventory.

applicable to organizations regardless of sector, and multiple transportation agencies and airports participate. TCR has a voluntary GHG reporting program known as the Carbon Footprint Registry (CFR) which recognizes participants, offers innovative reporting options, promotes and rewards leadership, and helps national and international entities build partnerships. Like ACA, the CFR has five progressive levels of achievement: Bronze, Silver, Gold, Platinum and Allstar (as shown in the box).

## State-Level Greenhouse Gas Targets and Regulations

At the state-level, 23 states and the District of Columbia have established future GHG targets (C2ES 2020). These targets are most often based on 2050 emissions relative to 1990 levels. Some states also have targets for 2030 and 2040. States are also beginning to regulate certain aspects of GHG emissions at airports or for airlines. For example, the California Air Resources Board (CARB) now requires that airport shuttles at its 13 largest airports be zero emission vehicles by 2035 (CARB 2019a).

## Air Quality Standards

Air quality remains a major driver of emissions reductions at airports. Under the Clean Air Act, the EPA is required to set National Ambient Air Quality Standards (NAAQS) for six air pollutants, which together are known as criteria air pollutants. After establishing the specific standards, EPA works with state and local governments to evaluate whether geographic regions meet the NAAQS based on the most recently available air monitoring data. When an area of the country has outdoor air pollution levels above the NAAQS for one of the pollutants, that region is considered to be in "nonattainment" and must develop plans within three years demonstrating how the region will achieve attainment.

With respect to aircraft engines, the Clean Air Act requires EPA to consult with FAA and gives FAA the authority to enforce EPA's aircraft engine emissions standards through its certification regulations. FAA is responsible for ensuring that these regulations do not pose conflicts with safety and other aircraft operational requirements.

## International Regulations and Goals

International regulation is very focused on aircraft emissions, rather than on airports. Below are several key organizations and initiatives involved in lowering GHG emissions from aircraft.

### *International Civil Aviation Organization*

The International Civil Aviation Organization (ICAO)—a specialized agency of the United Nations—has adopted two approaches to reduce $CO_2$ emissions from aircraft. These include the Carbon Offsetting & Reduction Scheme for International Aviation (CORSIA) and the Volume III to Annex 16 of the Chicago Convention (Environmental Protection).

CORSIA has several policy elements:

- A goal is set of achieving carbon neutral growth from 2020 onward and reducing net $CO_2$ emissions to half of 2005 levels by 2050.
- Reductions will be achieved by offsetting emissions through the process of an airline purchasing emissions units equivalent to its offsetting requirements or via the use of sustainable aviation fuel (SAF) to lower the offset obligations commensurate with the carbon intensity reduction of the SAF.
- Airlines with annual emissions greater than 10,000 tons of $CO_2$ are required to report their emissions on an annual basis, with monitoring starting on January 1, 2019.
- Emissions from domestic air travel are not included in CORSIA.

The objective of CORSIA is to implement market-based measures that address annual global increases in $CO_2$ emissions from international air travel for each year above the 2020 levels by comparing $CO_2$ emissions in future years to the average baseline $CO_2$ emissions between 2019 and 2020. From 2021 until 2035, if $CO_2$ emissions from international aviation exceed the average baseline emissions of 2019 and 2020, the sector's offsetting requirement is the difference between that year's emissions and the baseline emissions of 2019 and 2020. After 2035, emissions are intended to be reduced within the sector, for example, with efficiency improvements or low carbon fuels. One benefit of participating in the CORSIA voluntary program is that when "more States join the CORSIA, more emissions are covered by the scheme" and thus will help achieve "higher environmental integrity" (ICAO 2019).

CORSIA is implemented in phases and comprises states that participate on a voluntary basis during the pilot phase of 2021 through 2023 and the first phase of 2024 through 2026. There are 76 countries, representing 76% of international aviation activity, that have volunteered so far. The second phase of the CORSIA implementation is from 2027 through 2035 and is mandatory for all states that have above a 0.5% individual share of total international aviation activities in revenue ton kilometers (RTKs) in 2018. An RTK is "the utilized (or sold) capacity for passengers and cargo expressed in metric ton, multiplied by the distance flown" (ICAO 2019). This second phase of mandatory offsetting does not apply to least developed countries (LDCs), small island developing states (SIDS), and landlocked developing countries (LLDCs) unless they volunteer to participate. Though there are no offsetting obligations for flights to and from exempt nations, all nations are required to report total $CO_2$ emissions.

In 2017, ICAO adopted the Volume III to Annex 16 of the Chicago Convention (Environmental Protection), which has two elements:

- Aircraft $CO_2$ emissions standards for engines.
- A standard that applies to new aircraft type designs from 2020 and to aircraft type designs already in production as of 2023. In-production aircraft that do not meet the standard by 2028 will no longer be able to be produced unless their designs are sufficiently modified.

EPA and FAA traditionally work within the standard-setting process of the ICAO's Committee on Aviation Environmental Protection (CAEP) to establish international emissions standards and related requirements that individual nations later adopt into domestic law. In the past, ICAO has established international certification limits for nitrogen oxide ($NO_x$) emissions from jet engines. EPA has adopted ICAO's certification standards as national regulations. FAA, in turn, enforces these standards through engine certification.

Current $NO_x$ emissions standards for aircraft engines were established in 2014 and are more stringent than earlier standards. This is the fifth change since the original standards were agreed upon in 1981. New certification standards for aircraft are regularly being considered to further reduce total aircraft $NO_x$, smoke, and noise emissions. ICAO has also established aircraft engine certification standards that limit smoke emissions, as measured by a smoke number. The smoke standards took effect in 1983. Since smoke is an indicator of particulate matter (PM) emissions, these standards have been indirectly influencing aircraft PM emissions for the past 30 years. ICAO has now proposed PM certification standards for engines that, once finalized, will be adopted by EPA.

### *United Nations Sustainable Development Goals*

The United Nations Sustainable Development Goals (SDGs) were established in 2012 to address the global environmental, political, and economical challenges of today. SDG13 is focused on climate action by encouraging "urgent action to combat climate change and its impacts" (United Nations 2019). There are several specific targets associated with this goal, including to "integrate climate change measures into national policies, strategies and planning" and "improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning" (United Nations 2019).

To support companies in aligning their strategies with the SDGs, the United Nations Global Compact, GRI, and the World Business Council for Sustainable Development (WBCSD) developed the SDG Compass. The SDG Compass guides companies through the process of maximizing their contribution to the SDGs while preserving and enhancing business interests. Relevant to zero- or low-emissions planning, the SDG Compass encourages companies to implement solutions that combat climate change including obtaining electricity from renewable sources, increasing the efficiency of lighting systems, investing in technologies to capture and store carbon, and reducing GHG emissions from transportation.

Another United Nations initiative that complements SDG13 and zero- or low-emissions planning is Climate Neutral Now, through which companies, organizations, governments, and citizens pledge to measure their GHG emissions, reduce those emissions to the extent possible, and compensate for the rest through United Nations certified emission reductions (CERs). Airports Council International (ACI) supports Climate Neutral Now through its ACA program, which mirrors the objectives of the United Nations initiative.

### *International Air Transport Association*

The International Air Transport Association (IATA) seeks to address the global challenge of climate change and has adopted a set of targets to mitigate $CO_2$ emissions from air transport:

- An average improvement in fuel efficiency of 1.5% per year from 2009 to 2020,
- A cap on net aviation $CO_2$ emissions from 2020 (carbon-neutral growth), and
- A reduction in net aviation $CO_2$ emissions of 50% by 2050, relative to 2005 levels (IATA 2019).

IATA is determined to be part of the solution but insists that, in order to achieve these targets, a strong commitment is required from all stakeholders to work together through the four pillars of the aviation industry strategy:

- Improved technology including the deployment of sustainable low-carbon fuels,
- More efficient aircraft operations,
- Infrastructure improvements including modernized air traffic management systems, and
- A single global market-based measure to fill the remaining emissions gap.

### *Commercial Aviation Alternative Fuels Initiative*

The Commercial Aviation Alternative Fuels Initiative (CAAFI) is a coalition of aviation stakeholders who are interested in bringing commercially viable, sustainable aviation fuel (SAF) to the marketplace. CAAFI is engaged in various activities to enable and facilitate the near-term development and commercialization of such fuels. Bio-based fuels are commercially viable now and, in the future, synthetic jet fuel derived from carbon in the ambient air is expected to be available.

Depending on the feedstock and production pathway used, alternative aviation fuels may offer reductions in GHG emissions when compared to conventional fuels. For example, research suggests that hydroprocessed esters and fatty acids (HEFA) from bio-based oil feedstock can have as little as 20% to 40% the emissions of conventional Jet A, assuming there is no land-use change (Stratton et al. 2011, World Energy 2018). However, land-use change can be critical with any biomass, as converting tropical or peatland rainforest to biomass production can increase the life cycle emissions by several orders of magnitude over that of traditional Jet A. CAAFI and the aviation community are committed to carbon neutral growth starting in 2020 and are, therefore, interested in alternative jet fuels that have GHG reductions compared to standard petroleum-based jet fuels.

To the extent that airlines have access to environmentally beneficial alternative jet fuels for aircraft, the emissions associated with airline flights may be reduced on a life cycle basis. Aviation groups have agreed that a focus on "waste-based" feedstock, such as used-cooking oil, tallow from rendering livestock, municipal solid waste, and forestry residue is an effective way to avoid land-use change issues. Airports that own and operate ground service equipment can also gain environmental improvements in the operation of their own equipment, as alternatives for such equipment can reduce GHG and local emissions as well.

## 1.3 Build Business Cases for Zero- or Low-Emissions Planning Programs

Airport operators who are considering developing a zero- or low-emissions roadmap will need broad support from a diverse group of airport stakeholders. To attain buy-in from stakeholders, airport operators must demonstrate the benefits of zero- or low-emission planning.[2] A strong business case can help airport executives and governance look at zero- or low-emission planning as value additive and as good business, and not just as another cost.

This chapter describes how to create a compelling business case for a zero- or low-emission roadmap (Figure 4). First, the chapter describes the basics of constructing a business case, which may serve as a guideline for approaching stakeholders about developing a zero- or low-emission roadmap. Next, the chapter outlines business cases as key examples—along with references—to help build a business case tailored to a specific airport. Lastly, additional resources and benefits are described as potential avenues for strengthening and enriching these arguments.

[2]Note: Noise emissions are not a focus of this guidebook.


***Figure 4. Business cases for zero- or low-emissions roadmaps.***

## Basics of Constructing a Business Case

A strong business case is the key to gaining support for any initiative. A business case for a zero- or low-emissions roadmap should appeal to stakeholders and decision-makers by outlining how the organization can uniquely benefit from the initiative. Business cases are most often associated with added revenues but include consideration of risk and timelines.

The following outline provides an example of how an airport could structure a business case for a zero- or low-emissions roadmap. This outline is intended to be quite extensive. Smaller airports or those just starting out on zero-emissions planning may only need to develop a short business case (e.g., one to two paragraphs providing the overall rationale and expected benefits).

1. Summary of key points
   - Provide a concise summary of problems, potential solutions, recommended solutions, and key benefits of the business case that reflect an understanding of the recommended solution.
   - Some stakeholders and decision-makers will only read this section, so make certain it functions convincingly as a stand-alone document.
2. Introduction
   - Briefly introduce the business case topic, a proposal for developing a zero- or low-emissions roadmap.
   - Introduce any necessary context.
3. Description of the problem at hand
   - Describe the problems that a zero- or low-emissions roadmap could address.
   - Relate the problem to the airport's specific needs and goals.
   - Highlight the importance of solving the problem.
4. Discussion of potential solutions or actions
   - Discuss potential solutions for the previously described problems.
   - Be sure solutions include all options in a zero- or low-emissions roadmap and any alternatives.
   - Go into detail regarding logistics, benefits, costs, and risks of each potential solution.
5. Recommendation
   - Make a recommendation for the best course of action.
   - Discuss details about the recommended course of action.
   - Weigh the costs and benefits of the recommendation against other, previously discussed options.
   - Connect the benefits from the recommended course of action to the interests of the airport, stakeholders, and decision-makers.

6. Conclusions
   - Briefly summarize the problem and the recommended solutions.
   - Reiterate the importance of addressing the problem.
   - Reiterate the benefits of addressing the problem with the recommended solutions.

## Improved Bond Rating

Four key credit rating agencies are involved with airport bond issuance: Fitch Ratings (Fitch), Kroll Bond Rating Agency (Kroll), Moody's Investors Service (Moody's), and Standard & Poor's Global Ratings (S&P). The credit rating agencies issue periodic reports that include opinions related to the outlook for airport credits. These reports provide guidance to airports and other participants in the debt issuance process, ultimately impacting the costs of financing capital projects at airports.

Aggressive pursuit of zero-and low-emissions targets sends an important signal to credit rating agencies and has been shown to improve airport bond ratings (as shown in the box). Eliminating dependence on fossil fuels at an airport insulates the airport from the volatility of fossil fuel price fluctuations and reduces the probability of major revenue-interrupting shocks which helps de-risk future airport revenue streams. As a result, credit rating agencies have been publicly warning companies and government entities that unpreparedness for climate change will result in lowered future bond ratings (Flavelle 2019). The potential for bond rating improvements proves especially important for large- and medium-hub airports, which heavily depend on bonds for capital project financing.

### Emissions Reduction Record Improves Dallas/Fort Worth International Airport's Bond Rating

The CEO of Dallas/Fort Worth International Airport provided information on their emissions reduction record when having their bond rating evaluated. The airport received an improved bond rating to investors due to their strong efforts to reduce emissions.

## Improved Public Relations

The environmental impacts of air travel are well publicized, and travelers are increasingly conscious of the environmental impacts of their consumption habits (Miles 2017; Hackel and Sparkman 2018; Schlossberg 2017). Polls consistently indicate public support for green initiatives, such as carbon neutrality (Roberts 2018). At least 75% of Americans reported being "particularly concerned" about helping the environment as they go about their daily lives, 20% of adults said they make an effort to "live in ways that protect the environment" all the time, and 63% said they make an effort to do so at least some of the time (Anderson 2017). Due to overwhelming public support, a growing majority of consumers are willing to pay more for environmentally friendly products (Nielsen 2015). Additionally, citizens living in communities adjacent to airports are exposed to airports' on-site emissions and represent a key group of supporters of zero- or low-emissions planning.

A transition to zero- or low-emissions presents an opportunity for airports to appeal to an increasingly environmentally conscious market. A full 79% of corporate executives whose companies committed to the SBT initiative have reported boosting their brand reputations (Galvin 2018). Especially among younger populations, a reputation for sustainable practices and social responsibility could start to build brand loyalty and growth for an airport. Many airports have used their participation in ACA or their sustainability initiatives to enhance communication with their communities, elected officials, and other stakeholders. For example, San Francisco International Airport has made its annual Climate Action Plan reports, which provide information on the airport's progress towards its emissions reduction goals and initiatives, publicly available since 2011 on its website.

## Carbon Pricing Risk Mitigation

Carbon pricing has increasing support from governments, investors, and business executives across the world. At least 60 regional, national, or subnational jurisdictions have priced carbon in some capacity (Figure 5). Roughly one-quarter of all electricity consumed in the

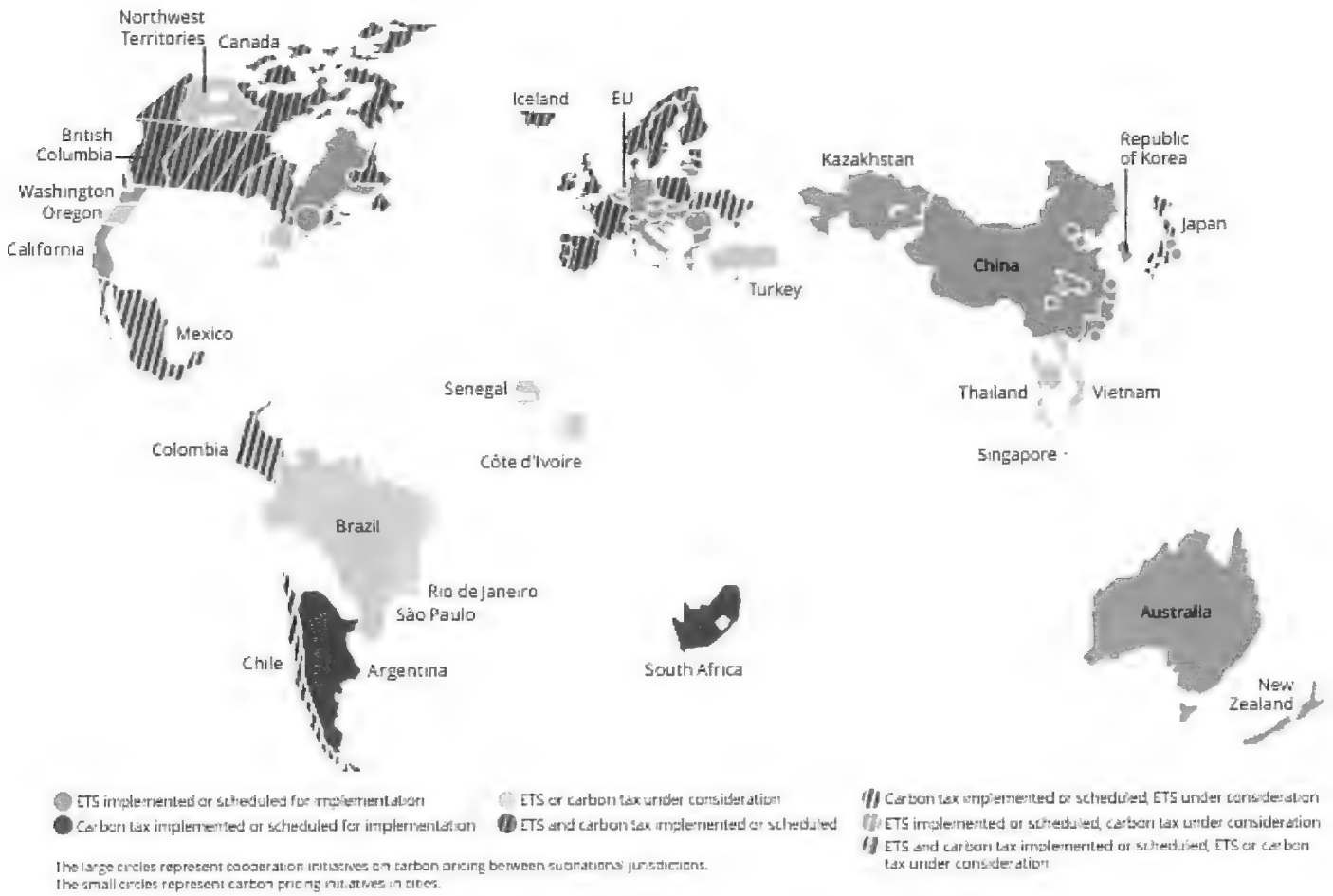


***Figure 5. Regional, national, and subnational carbon pricing initiatives (World Bank Group 2019) © World Bank.***

United States is currently carbon priced through state cap-and-trade programs. California and the Regional Greenhouse Gas Initiative (RGGI) are responsible for the carbon pricing in the United States, but they do not include aircraft emissions as part of their programs. RGGI is growing with Virginia poised to join in early 2021. Federal and state fuel economy and energy efficiency standards will continue to implicitly price carbon emissions (Topping 2019). Business leaders, responding to the economic risks posed by unabated climate change, are also increasingly calling for governments to price carbon pricing.

Long term, a high probability exists that airports will be required to internalize the social cost of carbon emissions. Airports should be prepared for the financial risk this presents. Global corporations have already started anticipating this risk, internally placing prices on their own carbon emissions to manage long-term investments (Topping 2019).

Table 3 presents a possible projection of costs from 2020 to 2050, given a scenario where airports must internalize the social costs of their Scope 1 and Scope 2 carbon (or carbon equivalent)

**Table 3. Annual social cost of Scope 1 and Scope 2 greenhouse gas emissions in 2019 dollars (EPA 2016b; LAWA 2016; Port of Portland 2017).**

| | 2020 | 2035 | 2050 |
|---|---|---|---|
| **Portland International Airport** | $5.8 million | $7.9 million | $10.0 million |
| **Los Angeles International Airport** | $16.9 million | $23.1 million | $29.1 million |

emissions. For simplicity, the projections assume constant yearly carbon emissions equal to those reported by either airport in 2016. The carbon's social cost derives from EPA estimates published in 2016 (converted to 2019 dollars). These projections use EPA's "high-impact rate" social cost of carbon estimate, ranging from $105 to $212 per ton, producing estimates close to those developed in economic and environmental literature.

Committing to a zero-carbon future insulates airports from risks presented by carbon pricing. The variability in methods governments use to calculate the social cost of carbon leads to a wide range of carbon costs over time. Therefore, the financial risk posed by carbon pricing is volatile from month to month (Figure 6).

### Social Cost of Carbon

According to the National Academies of Sciences, Engineering, and Medicine Board on Environmental Change and Society, the "social cost of carbon for a given year is an estimate in dollars, of the present discounted value of the future damage caused by a 1 metric ton increase in carbon dioxide ($CO_2$) emissions into the atmosphere in that year or, equivalently, the benefits of reducing $CO_2$ emissions by the same amount in that year" (Committee on Assessing Approaches to Updating the Social Cost of Carbon 2017). Greater guidance on determining a dollar value to assign to carbon emissions is offered by the EPA (EPA 2016a).

## Attracting Airport Partners

Businesses and partners that work in airports are key to an airport's operations. Using sustainability and green initiatives as features, airports may attract businesses and partners to their spaces. These businesses are valuable opportunities for airports to attract customers and further enhance their reputations. For an airport considering development of a zero- or low-emissions roadmap, it may be helpful to identify businesses and potential partnerships that would be attracted to an airport's sustainable practices.

Amazon serves as an example of an important partner, currently in the process of establishing its own fleet of aircraft and network of airport hubs. In 2019, Amazon announced its Shipment Zero initiative. Under Shipment Zero, all Amazon shipments are envisioned to become net zero carbon, with a midterm goal of one-half of all shipments becoming net zero carbon by 2030 (Clark 2019). To accomplish this, all parts of Amazon's supply chain must be included in its carbon accounting, including air shipments and all related operations and equipment at

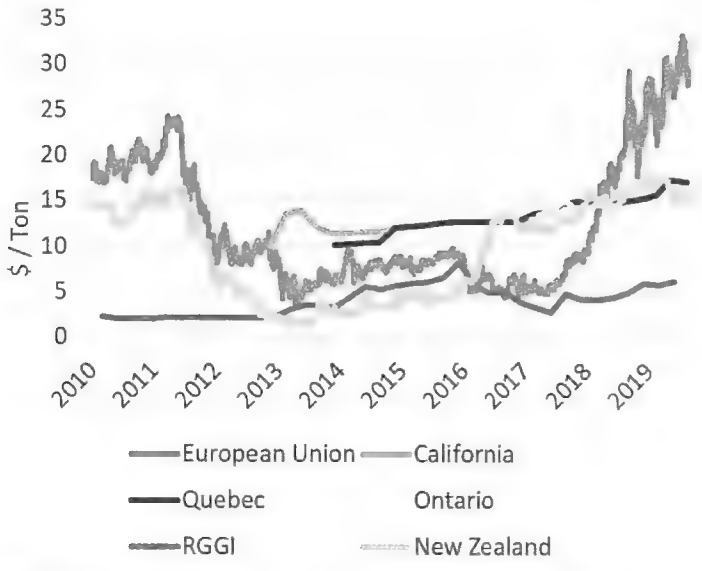


***Figure 6. Price per metric ton of $CO_2$, 2009–2019 (International Carbon Action Partnership 2019).***

airports. Airports that lower emissions become attractive sites for companies such as Amazon to expand their operations and offer significant business opportunities to airports that meet their standards.

## Improved Employee Relations

The public interest in sustainability extends to airport employees. Research suggests that pursuing zero carbon emissions can act as a centerpiece for the development of a sustainable, value-driven workplace culture (Bonini and Gorner 2011; Gammon 2014; Casey and Sieber 2016) and can reduce the total costs associated with employee severance and turnover. In a poll of working professionals, 71% were willing to take a pay cut to work in companies with missions and values they believed in. Additionally, a company having a positive impact on society served as a main source of pride for 46% of respondents (McQueen 2018). Airports with good reputations attract motivated and loyal employees, which feeds back to improving the airport's operations.

When airports make clear commitments to sustainability, employee motivation and engagement increase. Key to realizing these benefits is ensuring that airports engage airport staff, airline employees, and tenant employees in a common vision and a culture of sustainable thinking and practice. Training, management, and social activities that bring employees together from different sectors of the airport can help embed this culture.

### Importance of Grid Reliability

In 2017, Hartsfield-Jackson Atlanta International Airport suffered an 11-hour power outage, which caused major losses for airlines across the airport, including an estimated $50 million loss on Delta Airlines from canceled flights (Matousek 2017).

## Energy Resiliency and Efficiency

Zero- or low-emissions programs offer co-benefits, such as increased energy resilience and efficiency, which could provide long-term cost savings—as energy costs escalate and as protection from catastrophic events such as the 11-hour blackout at Atlanta in 2017. As each airport is unique, it will be the responsibility of airport operators to determine which technologies would best meet the airport's needs while reducing carbon emissions and producing cost savings. However, airports of many types have benefitted from the available range of technologies to increase resilience and efficiency while decreasing carbon emissions.

For example, San Diego International Airport leased its unused land in collaboration with Borrego Solar, installing 3.3 megawatt of solar panels connected to the airport via microgrid. NRG, owner of the panels, fronted the construction costs, and San Diego International Airport agreed to a 20-year power purchase agreement. This collaboration is expected to save the airport $8 million in energy costs over the agreement's lifetime, while avoiding over 3,700 metric tons of carbon emissions—the equivalent of 770 cars annually (Borrego Solar 2016). In addition to reducing its carbon emissions, the airport has become less vulnerable to price hikes in fossil fuels and to disruptions in grid power by diversifying its energy use and incorporating battery energy storage (DOE 2014; Port of San Diego 2018).

In another example, Appleton International Airport set goals to achieve carbon net zero by 2030 and has seen immediate benefits from making progress on its sustainability plans. After evaluating and retro-commissioning their facilities, the airport could demonstrate costs saved from making energy improvements. Using federal grants to fund initial renewable energy projects and reaping financial benefits from predictable, long-term energy costs, the airport could support

### Appleton International Net Zero Terminal

Appleton International Airport is a non-hub primary commercial service facility with over 718,000 passengers in 2018. Partnering with FAA's Sustainable Master Plan Pilot Program allowed the airport to design a general aviation terminal design projected to consume approximately 54,000 kilowatt hours of electricity annually, less than one-third the energy consumption of a similarly sized, traditionally designed building. The terminal will then produce the majority of its electricity on-site with a 25 kilowatt solar photovoltaic (PV) panel system, supporting Appleton International's goal of zero net carbon emissions by 2030 (ATW 2018).

future investments such as building a LEED Platinum General Aviation Terminal (Barrett et al. 2016).

Portland International Jetport in Portland, Maine, also took advantage of federal grants through FAA's Voluntary Airport Low Emissions (VALE) program to implement an energy efficiency project. The airport installed a geothermal heating and cooling system as part of its terminal expansion project. The geothermal system has provided a positive return on investment both in terms of reduced carbon emissions (estimated at 1,000 tons per year) and energy savings, estimated to be approximately $160,000 per year (Dolan, 2011).

Certain methods for lowering carbon emissions may offer immediate financial benefits, contributing to long-term resilience for airports. However, such actions are unique for each airport, as all airports have different energy demands and local renewable energy resources. Consequently, operators must evaluate their airport's facilities and determine the cost-effectiveness of different approaches before incorporating them into their business case.

## 1.4 Establish Roadmap Management and Governance

As with any airport project, an emissions roadmap requires a timetable, milestones, work plan, and management structure. The list below provides management and governance recommendations.

1. **Core Decision-Making Team.** Develop a Core Decision-Making Team composed of a mix of senior and mid-level staff of no more than 10 people. This team is described in more detail in Section 2.1. Research suggests that centralizing and formalizing the team organization is essential for addressing broad environmental challenges like emissions reductions, alternative fuels, and renewable energy (Sperling and Nesbitt 2001).
2. **Charter Statement.** Create an initial objective statement, vision statement, or charter that describes the underlying intent of the emissions roadmap. Ideally, this text is four sentences or less and can be used in email communications and as part of early-stage meetings to help guide discussions. This statement should be simple and easy to understand and should focus on the fundamental drivers of success for the roadmap process, rather than outlining a complex hierarchy of decision points and considerations.
3. **Fast-Track Delivery.** Commit to a short timeframe for roadmap development to maintain positive momentum. This guidebook recommends completing a polished draft within 3 months or less, followed by stakeholder engagement and finalization.
4. **Task-Oriented with Schedule.** Any multiday project requires a set of tasks and milestones that are needed to complete the project. The most common method for describing tasks and establishing a schedule is through a work plan and a Gantt chart that shows the duration and phasing of each task.
5. **Integrate Roadmap with Other Airport Plans.** Zero- or low-emissions planning at airports takes place relative to numerous other planning initiatives. Airports undertake master plans, sustainability management plans, and energy management plans, among other planning practices (FAA 2017a; Florida DOT 2010). These cycles are often not aligned with each other, and zero- or low-emissions planning tactics can be misaligned with their timing as well. To best ensure success of zero- or low-emissions planning programs, airports should be cognizant and consider—to the greatest extent possible—other planning processes. Often, incorporating zero- or low-emissions plans into master plans, sustainability management plans, or energy management plans is most effective, allowing the clout of those larger planning processes to be taken advantage of.

Table 4 presents a summary checklist of the actions involved in getting started on the development of a zero-emissions roadmap.

### How does Airport Ownership Impact the Emissions Roadmap?

The ownership and governance structures of airports can take on a range of forms but can generally be divided into a few high-level groupings, as is discussed in further detail in *ACRP Legal Research Digest 7: Airport Governance and Ownership* (Reimer 2017). Municipal, county, or state-owned airports may find it easier to obtain public funding from their parent agencies to pursue zero- or low-emissions efforts. Airports controlled by port, airport authority, or commission may have an even easier time moving forward with integration of zero- or low-emissions planning into larger planning efforts because of reduced need for communication with the municipality. Lastly, although privately managed airports make up only a small portion of U.S. airports, their structure allows the greatest level of autonomy, meaning they have the greatest leeway to merge zero- or low-emissions planning with larger planning efforts. Generally, the more ownership and autonomy an airport retains over its assets and operations, the greater agency it will have to pursue zero- or low-emissions planning and integrate those initiatives within larger airport planning efforts.

**Table 4. Checklist of actions to develop a zero-emissions roadmap.**

| Status | Action |
|---|---|
| ☑ | Ensure key staff have an awareness and basic understanding of **foundational concepts** such as the objective of the roadmap, scopes of GHG emissions, ownership and influence of emissions, general categories of emission sources, terminology used, and relevant industry programs such as ACA. |
| ☑ | Review relevant **voluntary programs, initiatives, and the regulatory landscape** for your state and region. This may include the latest versions of any state, county, city, and airport GHG goals, as well as documentation about whether the county is in an EPA non-attainment area. |
| ☑ | Establish **roadmap management and governance.** As appropriate for your airport, this may include the following: Form the Core Decision-Making Team; Develop a charter statement; Commit to a development schedule with tasks and milestones; Consider how to integrate the roadmap with other airport plans. |
| ☑ | Develop the **business case** for zero- or low-emissions planning, using the guidance in Section 1.3. Share the business case with airport leadership for buy-in and approval. |
| ☑ | Form other **stakeholder teams**, including the Implementation Team and Advisory Team, as described in Section 2.1. |
| ☑ | Review the airport's most recent **GHG inventory**, including data inputs and outputs, if one exists. Determine the need for updates to the inventory or to portions of the inventory (e.g., the need to compile information on additional scopes). |
| ☑ | Gather all relevant **historical information** about prior emission reduction projects at the airport. This will help celebrate prior efforts and determine what additional emissions reduction strategies may be feasible to include in the roadmap. |

CHAPTER 2

# Stakeholder Engagement

Stakeholder engagement is frequently cited as a critical element for successful GHG mitigation programs at airports. Engaging with stakeholders early and often provides a foundation for zero- or low-emissions planning that is informed, comprehensive, and supported. By drawing on a large pool of participants for the planning and implementation process, airports increase the likelihood that emissions mitigation initiatives become institutionalized and ingrained within existing planning processes.

This guidebook uses the same definition of stakeholder as *ACRP Synthesis 65: Practices to Develop Effective Stakeholder Relationships at Smaller Airports*—"any group or individual who can affect or is affected by the achievement of the airport's objectives" (Elliot, Chapman, and Kelly 2015). Figure 7 depicts key internal and external stakeholders at airports. Figure 8 shows the two steps outlined in this stakeholder engagement section.


***Figure 7. Internal and external airport stakeholders (Virginia Department of Aviation 2016).***

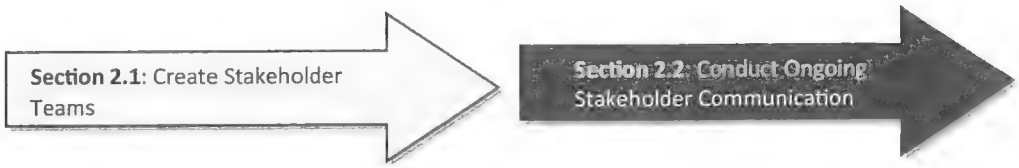


*Figure 8. Steps for stakeholder engagement.*

## 2.1 Create Stakeholder Teams

A critical first step to an effective engagement strategy is to develop internal and external teams of stakeholders who will guide the roadmap development process. This step must be undertaken early in roadmap development, so that there is ample time for stakeholders to buy into and provide input to the process.

This guidebook recommends using three separate but interlinked teams as described below and depicted in Figure 9. However, smaller airports may choose to reduce the size or number of stakeholder teams. For example, they may include only two or three individuals on the core decision-making team, or they may combine the core decision-making and implementation teams.

Regardless of the approach, the essential function of each team remains the same as described below.

- **Core Decision-Making Team.** This core group is internal airport staff, who are involved in every aspect of roadmap development from start to finish. This team should include the airport sustainability coordinator as well as a mix of senior and junior staff, who are responsible for developing the roadmap, building the business case, prioritizing and selecting initiatives for future implementation, organizing stakeholder activities, and communicating with internal and external stakeholders.
- **Implementation Team.** This team is internal and external stakeholders responsible for implementing the roadmap activities following the roadmap development. These stakeholders also assist during roadmap development by guiding the vision, goals, and initiatives so they are implementable and integrated into all aspects of airport operations. Implementation team members are important agents for change and will be actively

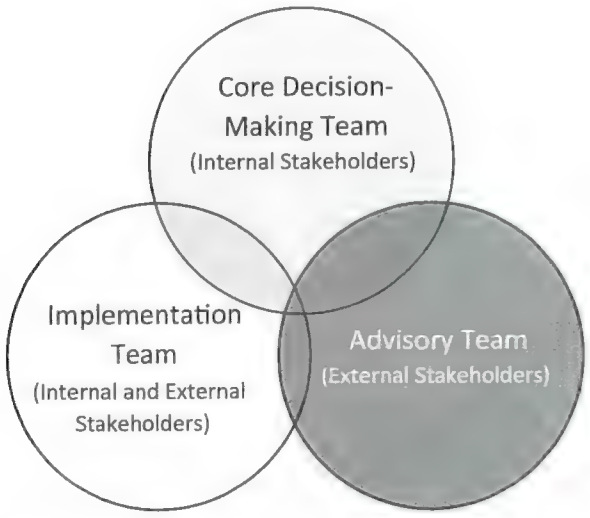


*Figure 9. Recommended stakeholder teams.*

involved in enhancing communication, education, and collaboration to achieve the airport mission by participating in the planning process, generating ideas for potential initiatives for emission reductions, assisting in the development of key performance indicators (KPIs) for tracking progress, acting as a bridge between employee ideas and practical implementation, and supporting ongoing implementation of the roadmap.

- **Advisory Team.** This team comprises external stakeholders who support both the core decision-making and implementation teams by reviewing draft versions of the roadmap and identifying opportunities to increase the roadmap's reach and influence within the region. *ACRP Report 158: Deriving Benefits from Alternative Aircraft-Taxi Systems* (Fordham et al. 2016) found that "very few airports engage in dialogue mechanisms with surrounding communities, such as advisory committees that include citizen representatives, and rarely continue them beyond the life of the specific study for which they were convened." The study concluded that "ultimately, changes in attitudes and practices for both airports and their hosting communities will remain unchanged until they develop a new set of processes for shared communication and cooperation." The study recommended that "airports establish standing committees that focus on improving airport-community relations" during a specific project, study, or planning effort. Vancouver International Airport is one such airport that has established standing committees to regularly engage on issues of mutual interest to the airport and its community members (as shown in the box).

**Advisory Team at Vancouver International Airport**

Vancouver International Airport has two public committees that represent citizens and key stakeholder organizations: the Environmental Advisory Committee, which provides input and suggestions on the airport's environmental practices and programs, and the Aeronautical Noise Management Committee, which provides a forum to noise management (Leahu-Aluas et al. 2018).

## Identify Stakeholders

The core decision-making team is the first team needed and will identify and create the implementation and advisory teams. Although every airport is different, the core decision-making team composition will likely initially be formed through conversations between the airport sustainability office and airport senior management. To develop the other two teams, the core decision-making team should cast a wide net, among both airport employees and the surrounding communities so that relevant groups are not excluded. *ACRP Synthesis 85: Alternative Fuels in Airport Fleets* (Morrison 2017) recommends identifying stakeholders with several traits:

- Have influence or decision-making power,
- Have information that cannot be gained otherwise,
- Are critical for successful implementation,
- May challenge emerging strategies,
- Interact most frequently with the airport,
- Depend financially on airport operations and activities,
- Can legitimately claim to represent a constituency,
- Belong to a group to whom the airport has legal or financial responsibilities, and
- Are the intended audience of airport policies and value statements.

Each stakeholder has particular interests that determine how to effectively engage and communicate with that stakeholder, and how to request their participation in one of the three teams. Table 5 describes the interests of various airport stakeholders (modified from Amaeshi and Crane 2006).

In the process of identifying stakeholders, the core decision-making team should actively engage potential candidates for each team to understand their specific interests. To help

**Table 5. Stakeholders and potential interests.**

| Stakeholder Group | Potential Interest Categories |
|---|---|
| National/state/regional/local government | policy formulation, regional development, funding, safety, social and economic development, environmental regulations, contribution to local economy, safety and health regulations (such as the Occupational Safety and Health Administration, regarding the types of materials used and disposed of), adherence to policy and law |
| Airport organization | growth, development, maintenance, operations, safety, workforce, financial stability |
| Airport employees | employment, opportunity, growth, retention, airport initiatives, treatment of employees, benefits, trainings, safety, benefits/coverage, diversity |
| Airport service partners/airport tenants/vendors/airlines | commercial development, operations, policies, accessibility, parking, business traffic, security, health and safety code adherence, opportunities for economic development |
| Airport users | airport services/route development, accessibility, cost, safety, operations and policies, parking |
| Communities near airport operations | potential environmental impacts from airport operations, employment opportunities, access to aviation, opportunities for local business development, noise, air quality, airport development, traffic, parking, safety, accessibility, investment |
| Nongovernment organization (such as environmental groups) | global/regional/local environmental impacts, human rights, access to facility for meetings, philanthropy, communication |
| Airport suppliers | growth of market, accessibility, ability to maintain airport and airline contracts |
| Providers of other local transport services | growth and integration of services, accessibility, costs |

### Seattle-Tacoma International Airport Best Practices for Stakeholder Engagement on Emissions Mitigation

According to Seattle-Tacoma International Airport staff, two approaches to developing strong airport-tenant relationships around emission reduction initiatives are to create award programs that annually celebrate tenants who go the extra mile and to directly assist airlines in applying for grant funding.

guide this process, below are sample questions for candidate stakeholders (Amaeshi and Crane 2005):

- Describe your interest in our airport.
- What topics or areas are most important to you and why?
- What do you expect from your relationship with our airport?
- What could the airport do to better support the community (internal or external)?
- What are the opportunities for collaboration between the airport and your organization?
- What is your current opinion of our airport?
- What are general industry challenges or potential future challenges?
- Where are opportunities for stakeholder engagement with the airport?
- What engagement activities would you like to see?

## Identify Key Stakeholder Roles

While the exact composition of each stakeholder team will be different for every airport, reflecting the different operating environments, political dynamics, emissions reduction strategies, and many other factors, it is important to include several types of stakeholders in order to build strong stakeholder buy-in and ongoing support to roadmap planning, implementation, and monitoring. These stakeholders can help communicate the goals of the effort and establish partnerships within the airport:

- **"C-Suite" Champion.** Having members of the airport's executive team on the core decision-making team to advocate in support of zero- or low-emissions planning greatly contributes to the success of emissions reduction efforts. As a member of the core decision-making team, a C-Suite champion would be key in laying out the vision and overall objectives for roadmap planning, helping identify key members of the implementation and advisory teams, providing input and approval of goals and KPIs, and being updated on major milestones along the implementation and monitoring process. Subsequently, this key team member can dedicate

resources to ensure that zero- or low-emissions planning is prioritized, generate buy-in from the board, and publicize airport achievements.

- **Department Leaders.** Senior airport department staff are foundational to the implementation team. This team should include staff from the finance and administration, planning and engineering, operations, and maintenance departments. These staff will help set the roadmap goals, coordinate with their staff to execute the actions necessary in pursuit of those goals, and ensure that data are gathered to track progress against the KPIs. Ideally, the selected leaders will be adept at coordinating across organizational silos so true partnerships can be created among departments.
- **Data Managers.** Collecting emissions data is critical for establishing benchmarks, setting goals, and tracking progress. Including data managers ensures that the Implementation team has a comprehensive understanding of the available current and historical emissions data. Data managers can also help facilitate conversations to determine whether additional data needs to be collected to inform the planning process, and how that data can be obtained, and can monitor the data collected against the roadmap KPIs.
- **Tenant Liaisons.** Tenants are critical to airport emissions, with an especially large role in Scope 3 emissions. As such, tenants are critical to the implementation team. Airport staff, who frequently liaise with tenants, should also be included in the implementation team. Their participation helps ensure there is coordination on emissions reduction efforts between airport staff and tenants to the extent possible.
- **Communications and Marketing Staff.** Airport staff with a background in communications and/or marketing have been trained on effective techniques to engage stakeholders, frame messaging, and manage public relations. Acting as key members of the implementation team, communications and marketing staff should work hand in hand with technical staff to translate technical information into messaging that resonates with different audiences. They can ensure that stakeholder engagement related to zero- or low-emissions planning is aligned with broader engagement efforts and consistent with the brand and reputation of the airport.
- **Airport Governing Body.** The airport's board should be involved in the advisory team, contribute to the roadmap vision and overall objectives for zero- or low-emissions planning, and be kept up to date on major milestones in the roadmap planning and implementation process including reviewing goals, activities, and KPIs. Board members can also provide strategic direction throughout the process and may bring innovative emissions reduction ideas from the organizations they represent.

### Cascading Impacts of San Francisco International Airport's Top-Level Buy-In

San Francisco International Airport has found top-level buy-in to be an instrumental factor in its zero-emissions planning. It has had strong support from the San Francisco Mayor's Office and C-Suite executives at the airport, with this support trickling down to benchmarking in the strategic plan, a committee focused on carbon neutrality and deep de-carbonization (with a $100 million budget), and another committee focused on a portfolio of emission reduction initiatives under the airport's $7.4 billion capital program.

Once the members of each stakeholder team are identified, members must understand and commit to their roles. An effective tool for assigning specific roadmap responsibilities to specific individuals is through a responsibility assignment matrix (RAM), a method used to assign and display the responsibilities of individual stakeholders or teams to accomplish the roadmap activities and goals.

A RAM clearly articulates all potential activities needed during roadmap development, stakeholder responsibilities for each activity, and the level of responsibility for each stakeholder. The example shown in Table 6 uses the RACI responsibility matrix model, where each cell in the matrix lists the level of responsibility by task and stakeholder. In this model, the roles are labeled:

- **R** = Responsible. The individuals who complete the tasks.
- **A** = Accountable. The individuals who are ultimately responsible for completing the tasks.
- **C** = Consulted. The individuals whose opinions are sought such as for subject matter expertise.
- **I** = Informed. The individuals who are kept up to date regarding major milestones and task completion.

**Table 6. Responsibility assignment matrix.**

| Activity | Person A | Person B | Person C | Person D | Person E | Person F |
|---|---|---|---|---|---|---|
| Identification of alternative fuel surface vehicles | I | R | A | | | C |
| Lighting upgrades, automation and controls, continuous commissioning | I | R | A | | | C |
| External reporting | I | A | | A | R | |

## Gathering Input to Inform Emissions Reduction Strategies

Airports have used several successful strategies for receiving input from stakeholders, including:

- Surveys and interviews (online, mailed postcards, in person, or over the phone),
- Regularly scheduled teleconference or in person meetings on defined topic areas,
- Town hall meetings and open houses,
- Focus groups or workshops,
- Online discussion forums and social media platforms,
- Comment collection systems throughout the airport,
- Participation in local government meetings and on local boards,
- Advisory committees with community representatives,
- Working groups on specific topics such as energy efficiency, and
- Airport tours (for community members, businesses, etc.).

Several of the strategies listed above could apply to both internal and external stakeholders, while some may be best suited for specific stakeholder groups within one of those categories. Again, gaining an understanding of stakeholder preferences and relationships to the airport will determine which avenues are most appropriate and what timing or frequency is appropriate. Regardless of the input strategies used, internal stakeholders such as department leaders are best suited to inform emissions reduction strategies for Scope 1 and Scope 2 emissions while stakeholders such as tenants and external community groups should inform Scope 3 emissions reductions.

For the purposes of zero- or low-emissions planning or any type of strategic planning, airports should devise a strategy for prioritizing input. Airports may not be able to act on every piece of input received from stakeholders but should be able to justify how input was responded to. The core planning team is encouraged to come to a consensus on the airport's priority areas related to zero- or low-emissions planning. Some of the factors that could affect how an idea or action is prioritized are the impact to airport operations, impact to emissions reductions, achievability, time scale, cost, associated potential risks and opportunities, and relevance to stakeholders.

### Focus on Emissions Reduction, Not Glossy, Glamorous, "Greenwashed" Projects

One anonymous airport noted that there can be parties within the airport pushing for high visibility projects, but that those projects may not offer the greatest emissions reduction benefits. When engaging stakeholders and presenting project options to decision-makers, it is important to maintain focus first on the emissions benefit of a potential effort. Although public relations benefits should be a consideration of zero emissions planning, care should be taken to ensure they do not carry an outsized weight.

## 2.2 Conduct Ongoing Stakeholder Communication

Stakeholder engagement is not a static, one-way process comprised of messaging from the airport or from the core decision-making team to the advisory team. Effective stakeholder engagement should be a true collaborative and reciprocal process that can help establish strategies for achieving mutual benefits and overcoming challenges. It is important for airports to develop and conduct ongoing stakeholder engagement through the use of teams, as well as with the public at large, and not just when conducting planning and large development projects. An ongoing communication effort can enhance overall roadmap planning and implementation collaboration, reduce public confusion and skepticism about project development, and assist in generating stakeholder buy-in for airport decisions. In addition, establishing mechanisms and strategies for communicating and engaging with stakeholders means that airports do not have to kick-start a new effort each time they embark on a large initiative. Continuous engagement also fosters trust and predictability among stakeholders. Ideally, an airport embarking on zero- or low-emissions planning would integrate stakeholder engagement related to the planning process with ongoing engagement efforts.

Stakeholder engagement and communication includes marketing and public relation efforts; tenant, employee, and passenger surveys; strategic planning including identifying stakeholder roles and responsibilities; and outlining general effective communication practices. Table 7 provides a number of tools and resource for ongoing communication and engagement.

Evaluation is a necessary part of any stakeholder engagement program. Airports should periodically (at least annually) assess stakeholder engagement activities and the types of participants engaged to identify areas for improvement and opportunities to streamline the process, and to determine whether to cast a wider net. Airports should be receptive to feedback on which engagement methods are working, which engagement methods are not working, what could be done differently, and whether the engagement process is helping the airport meet its zero- or low-emissions goals.

To inform the evaluation process, airports are encouraged to track and report stakeholder engagement statistics. Tracking logical metrics can help airports evaluate whether their approaches are effective, identify trends over time, and have quantitative evidence to report and communicate to their stakeholders. There are several types of potential metrics:

- Number of community events held to inform stakeholders about the airport and its zero- or low-emission efforts,
- Number of participants at meetings and events focused on zero- or low-emissions planning,
- Number of airport-hosted stakeholder engagement sessions focused on emissions,
- Number of downloads per year of the airport's zero- or low-emissions planning-related materials from its website,
- Tracking email and phone call-based complaints and working toward a reduction over time, and
- Number of "likes" or "follows" for the airport's posts on social media platforms (such as Facebook, Twitter, and Instagram) relevant to emissions reduction efforts.

As a complement to quantitative metrics, airports can also gather qualitative feedback through surveys or one-on-one discussions and can showcase quotes from stakeholders that capture how their involvement enhanced zero- or low-emissions planning at the airport.

**Table 7. Suggested resources for additional guidance.**

| Tool and Resource | Report/Author | Description |
|---|---|---|
| *Marketing Guidebook for Small Airports* | *ACRP Report 28* (2010) | This resource guide includes the basics of a marketing plan, such as templates; analysis of strengths, weaknesses, opportunities, and threats (SWOT); and an introduction to marketing and public relations tools. |
| *Guidebook for Conducting Airport User Surveys* | *ACRP Report 26* (2009) | This resource offers methods and information to conduct effective user surveys. The report covers air passenger surveys, employee surveys, tenant surveys, surveys of area residents, surveys of area businesses, and cargo surveys. |
| *Practices to Develop Effective Stakeholder Relationships at Smaller Airports* | *ACRP Synthesis 65* (2015) | This report offers tactics for building effective stakeholder relations, including case studies featuring successful examples. Appendix C of the report provides a checklist of practices to build stakeholder relations. The checklist serves to assess organizational readiness, formulate strategies, implement initiatives and programs, and evaluate outcomes. |
| *Strategic Planning in the Airport Industry* | *ACRP Report 20* (2017) | This report provides practical guidance on the strategic planning process for airports. It includes a discussion on identifying stakeholders to involve in strategic planning and a corresponding worksheet to determine the extent of their involvement. |
| Stakeholder Engagement: A Mechanism for Sustainable Aviation | Amaeshi and Crane (2006) | This paper discusses stakeholder engagement and includes a checklist on good practices for stakeholder engagement. |
| Community Involvement Manual | FAA (2016) | This manual provides FAA practitioners with the knowledge and resources to facilitate meaningful community involvement including effectively engaging communities, encouraging exchange of information, and having community viewpoints heard. It provides guidance that supplements applicable public participation provisions in relevant FAA orders. |
| Sustainability Reporting Guidelines & Airport Operators Sector Supplement | GRI (2011) | GRI helps organizations understand and communicate their impacts on issues such as climate change, human rights, and corruption. This resource tailors GRI's sustainability reporting guidelines to airport operators. |
| Integrated Reporting: Performance Insight Through Better Business Reporting | KPMG (2011) | This report discusses integrated reporting, an approach that focuses on interdependencies with an organization's strategy, business model, and context; its holistic historic performance; and its ability to keep achieving performance measures. |
| PBN Blueprint Community Outreach Task Group | RTCA (2016) | This resource provides a detailed list of best practices for community outreach to support Performance Based Navigation implementation and includes activities related to stakeholder engagement, outreach strategies, identification of success metrics, and incorporation of lessons learned. |
| Analysis of Airport Stakeholders | Schaar and Sherry (2010) | This paper identifies airport stakeholders, their objectives for the airport, and the relationships between the stakeholders. |
| Virginia Airports Sustainability Management Plan Commercial Service Supplement Appendix B: Guidance on Stakeholder Engagement | Virginia Department of Aviation (2016) | This appendix provides a best practice overview for airports initiating stakeholder engagement as part of a sustainability program. It provides a structure for the stakeholder engagement process and step-by-step guidance within the process. |

CHAPTER 3

# Setting Emissions Goals, Baselines, and Targets

This chapter describes a 5-step process for setting an emissions goal, based on guidance from the Greenhouse Gas Protocol on emissions mitigation goal setting (WRI 2014). As with other chapters, steps presented in this chapter, shown in Figure 10, should be performed iteratively and in conjunction with the other steps.

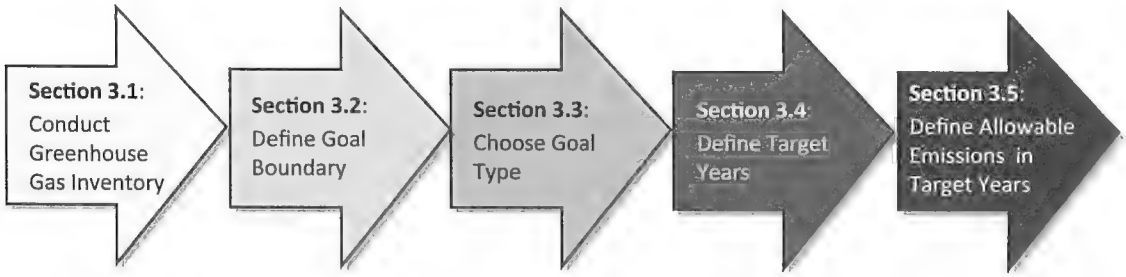


***Figure 10. Steps for setting emissions goals, baselines, and targets.***

## 3.1 Conduct Greenhouse Gas Inventory

A first step to setting an emissions goal is to conduct a GHG inventory—that is, an accounting of all emission sources and sinks from airport activities. For an airport, this involves the following steps (see *ACRP Report 11* and *ACRP Synthesis 85* for additional guidance):

1. **Review background information**, including understanding any new protocols or standards that have been implemented since the airport's prior emissions inventory;
2. **Collect energy and emissions documentation**, such as utility bills, fuel logs, airport activity levels, and other similar information;
3. **Calculate emissions** at the airport using tools, calculators, and established processes—a recommended tool for U.S. airports is the Airport Carbon and Emissions Reporting Tool (ACERT); and
4. **Develop an inventory report**, which clearly communicates emissions trends with the public.

Resources that provide detailed information on how to conduct a GHG inventory are included in Table 8.

### Additional Benefits of Collecting Emissions and Energy Data

Collecting data for a GHG inventory can present some initial hurdles regarding internal processes and figuring out what departments hold what information. However, communication across departments to collect this information and having these departments talk to each other can offer benefits. For example, Austin-Bergstrom International Airport saved about $1 million just by tracking and more closely monitoring its utility bills.

**Table 8. Tools and resources for conducting greenhouse gas inventory.**

| Tool and Resource | Author | Description |
|---|---|---|
| ***ACRP Report 11: Guidebook on Preparing Airport Greenhouse Gas Emissions Inventories*** | Kim et al. (2009) | This resource guide is designed to help airport operators and others prepare an airport-specific inventory of GHG emissions. |
| **Airport Carbon and Emissions Reporting Tool (ACERT) v. 6.0** | ACI (2019) | This tool provides a method to measure an airport's GHG emissions by source and generates a comprehensive GHG emissions inventory report that highlights the airport's performance based on emissions intensity. |
| **Guidance Manual: Airport Greenhouse Gas Emissions Management** | ACI (2009) | This manual provides airport operators guidance on managing GHG emissions, including how to conduct a GHG emissions inventory and which airport sources to include. |
| ***The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard*** | WBCSD and WRI (2015) | This widely adopted standard provides step-by-step guidance for companies and other organizations to use when quantifying and reporting their GHG emissions. |

### Using ACERT

ACI developed the Airport Carbon and Emissions Reporting Tool (ACERT), a free, Excel-based tool for airports to develop carbon emissions inventories. The tool is supported by ACI staff and is regularly updated. At the time of this guidebook's publication, version 6.0 is available. ACERT is consistent with the internationally recognized Greenhouse Gas Protocol. The tool and a user manual can be downloaded from ACI's website. ACERT can be used to develop emissions inventories for Scope 1, Scope 2, and Scope 3 and is also accepted for purposes of ACA. To use the tool, airports should read the user manual and the "Intro" tab in the Excel document prior to beginning the calculations to understand the data collection requirements. Airports should further confirm that the emissions factors built into the tool are the most accurate for the airport's location or should manually enter the correct emission factor. Though the tool is intended for use by staff with no prior inventory development experience, it is recommended that the results be reviewed closely for accuracy.

## 3.2 Define Goal Boundary

The next step is to define the goal boundary—that is, the geographic area, emission type, scope, timeline, and airport activities that will be within the goal. This boundary may differ from the boundary in the inventory and therefore is a separate step in Chapter 3. For example, the inventory may include all airport-owned (including tenant-operated) spaces, but the emissions goal may include only airport-owned and operated spaces. How the boundary is defined can have a significant impact on achieving the mitigation goal as well as on the opportunities available for achieving that goal. Note that the airport should consider and harmonize its emissions goal with the goals of the surrounding regional governments.

Another important note is that setting soft goals can sometimes be appropriate, especially if they are oriented toward the long term and their purpose is to set a specific intent. Soft goals are not as measurable or quantifiable as fixed goals that set the time frame, emission type, and scope and that are generally actionable. But soft goals can be acceptable if elements such as time frame cannot be ascertained at the time goals are set. One example is if an airport sets a long-term goal to achieve zero-emissions but cannot yet set a date for achieving it.

**Table 9. Questions to answer when defining airport emissions goal.**

| Question | Options | Example |
|---|---|---|
| **Reduction in what?** | Emissions | 50% reduction in metric tons of $CO_2$ by 2030 |
| | Emissions intensity | 50% reduction in $CO_2$ per passenger by 2030 |
| **Relative to what?** | Historical year | 50% reduction in metric tons of $CO_2$ by 2030, *relative to 1990 levels* |
| | Baseline scenario | 50% reduction in metric tons of $CO_2$ by 2030, *relative to the baseline scenario* |
| | No reference | Carbon neutral by 2030 |
| **Reduction or stabilization?** | Reduction in emissions | 50% reduction in metric tons of $CO_2$ by 2030 |
| | Stabilization of emissions | No *growth in $CO_2$ emissions* after 2025 |
| **Which gases?** | $CO_2$ emissions | 50% reduction in metric tons of $CO_2$ |
| | GHG emissions | 50% reduction in metric tons of gases regulated under the Kyoto Protocol: $CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$, and $NF_3$ |

## 3.3 Choose Goal Type

All emissions goals share the same underlying objective—to reduce emissions—yet they can differ materially in how they are worded. An airport should seek to answer the four questions shown in Table 9 along with possible answers and examples.

How best to answer these questions depends on airport-specific preferences, including the desired level of transparency, simplicity, and benchmarking desired. If the airport also uses a voluntary emission reduction and reporting program, the program may include requirements for the goal.

## 3.4 Define Target Years

Choosing a target year—that is, the year in which an airport needs to meet its emissions goal—involves choosing a base year (if applicable), deciding whether to adopt a single-year or multiyear goal, and choosing the target year. These three steps are described below.

### Choose Base Year

A base year is the reference year from which progress toward a goal is measured. Goals that go to zero (e.g., net zero, zero emission) do not need a base year since zero implies an absolute, not relative, reduction. For goals with a base year, the choice depends on the desired stringency of the goal. For example, an 80% reduction relative to 2005 levels may be much easier to achieve than an 80% reduction relative to 2015 levels if emissions grew in those 10 years. Another consideration is that having a single base year (e.g., 2005 levels) simplifies the process for goal setting, tracking, and reporting. However, caution should be taken if using a single base year because of year-to-year variations in emissions. Some organizations, therefore, average across an emissions period that uses multiple years. As of the writing of this guidebook, many airports are opting to set targets of carbon neutrality and carbon free, which do not require a base year.

### Choose Whether to Adopt a Single Target or Set of Targets

Adopting a single target year may be simpler to convey to airport stakeholders, but multiple years may be advantageous from a climate change perspective to avoid situations in

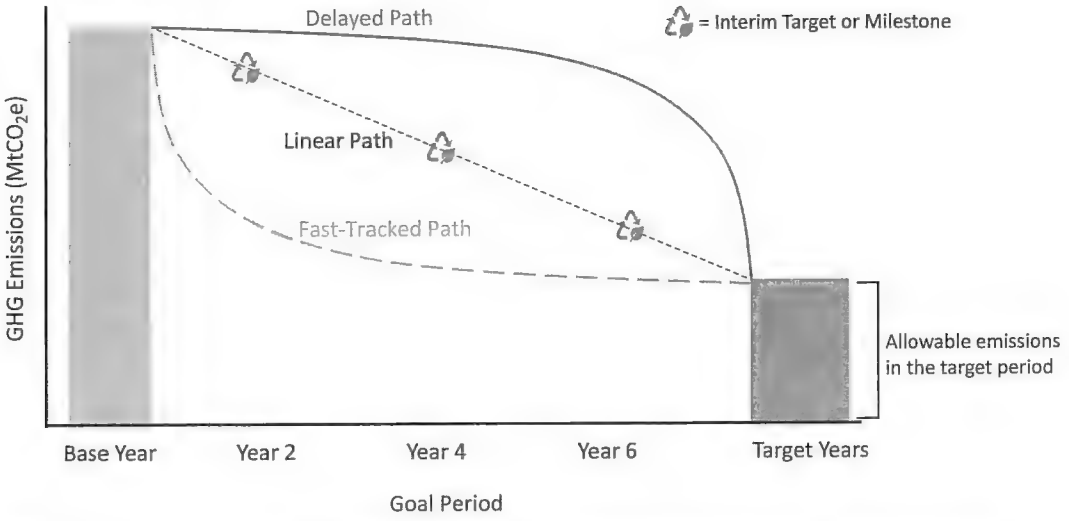


***Figure 11. Delayed* (top), *linear* (middle), *and fast-tracked* (bottom) *emissions reduction schedules.***

**Century Agenda Strategic Objectives of the Port of Seattle (Seattle-Tacoma International Airport)**

The Port of Seattle's Century Agenda Strategic Objectives are an example of ambitious GHG goals (Port of Seattle 2017).

- Scope 1 and Scope 2 emissions shall be:
  - 15% below 2005 levels by 2020.
  - 50% below 2005 levels by 2030.
  - Carbon neutral by 2050 or carbon negative by 2050.
- Scope 3 emissions shall be:
  - 50% below 2007 levels by 2030.
  - 80% below 2007 levels by 2050.

which an airport reduces emissions shortly before a target year. An example of Seattle-Tacoma International Airport's multiyear targets, broken down by emission scope, is shown in the box.

Indeed, the impact on climate change from airport activities is closely related to the total cumulative amount of GHG emissions released over time. If users of this guidebook have reasons to avoid multiple targets, then the minimum best practice is to set milestone years, which are less formal than official targets but still allow an airport to assess progress toward an ultimate emissions goal.

Figure 11 shows a conceptual diagram of an emissions reduction target. Three pathways are shown that achieve the eventual emissions target: a linear reduction schedule, a fast-tracked reduction schedule, and a delayed reduction scheduled. Though all paths achieve the target, the fast-tracked path will have the fewest cumulative emissions by the target year, whereas the delayed path will have the highest. Cumulative (in addition to annual) emissions are an important consideration for airports interested in true contributions to climate change mitigation. Because cumulative emissions are what influences climate change, and because GHGs are long-lived, earlier action is preferable: faster reductions provide benefits over a greater duration.

## Choose the Target Year

The choice of the target year or years depends primarily on the desired stringency of the goal. Obviously, for a given level of emissions reduction, a nearer-term goal (e.g., 2030) does more for climate change mitigation than a longer-term goal (e.g., 2050). At the same time, a longer-term goal may allow an adequate time horizon to conduct the necessary capital planning and expenditures.

## 3.5 Define Allowable Emissions in Target Years

A final step is to determine the maximum quantity of emissions in the target year. Best practices for developing goals include being organized, ambitious yet reasonable, and concrete (EPA 2019). These three practices are summarized here in the context of an airport.

**Be Organized**

- Goals should be clear and concise. To best develop buy-in and make them understandable, a short direct statement is usually better.
- Multiple tiers of goals can be useful. The highest tier might be qualitative and framed to relate to valued stakeholders. An example is to mitigate the airport's impacts to climate change and thus climate change's impacts on our communities. Subsequent tiers should be more specific and quantitative.

**Be Ambitious and Reasonable**

- Goals should inspire airport staff and community members to act but not be so ambitious that they intimidate. Some goals could be more aggressive to complement more achievable ones, or each goal could seek to meet an ambitious yet reasonable balance.
- Consider including goals for which the airport has already made some progress. This early progress can help accelerate the initial momentum and encourage further changes.

**Be Concrete**

- Qualitative goals can be useful from a communications and buy-in perspective, but quantitative, measurable goals are most useful for actually driving emissions reductions.

An additional consideration when setting the level of an emissions goal is to make the goal a science-based target (SBT). A target is science-based if it is developed in line with the scale of decarbonization necessary to keep the average global temperature increase below 2°C from preindustrial levels, as discussed in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

The SBT Initiative (SBTi) is a joint venture between CDP, World Resources Institute, the World-Wide Fund for Nature, and the United Nations Global Compact and is dedicated to encouraging private businesses to set and promote science-based decarbonization goals. As of January 2021, there are 604 businesses registered and taking action toward reducing GHG emissions with the SBTi.

The latest guidance from the SBTi recommends setting temperature targets at either 1.5°C or well below 2°C from preindustrial levels.

Currently, the only airports or port authorities in the world that are registered with the SBTi are the Port Authority of New York and New Jersey (PANYNJ), Auckland International Airport, and Heathrow International Airport. For PANYNJ, for example, the SBT is a 35% reduction in GHGs by 2025 and a long-term goal of 80% by 2050 (CDP et al. 2020).

CHAPTER 4

# Emissions Reduction Strategies

A core element of an emissions roadmap is a description of strategies the airport plans to use to reach its ultimate emission goals. Chapter 4 provides guidance on how to identify and select these strategies. The chapter is organized in four parts, which are summarized in Figure 12. Note that Sections 4.1 through 4.3 describe methods for reducing emissions and are in order corresponding with how most airports approach emissions planning. Section 4.4 describes how best to select the strategies identified in Sections 4.1 through 4.3. The quick start actions in the box are ideas for initiating the search for strategies.

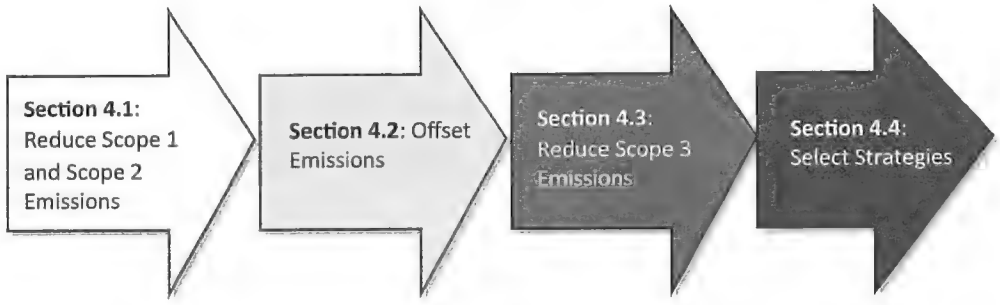


***Figure 12. Steps to identify emission reduction strategies.***

**Quick Start Actions to Help Select Emission Reduction Strategies**

Use these actions to help select emission reduction strategies.

- **Focus on the largest emission sources.** Begin the search for viable strategies by identifying the largest emissions sources in the GHG inventory (discussed in Chapter 3). At many airports, Scope 2 electricity emissions are the largest, which justifies spending more time and resources on identifying ways to reduce Scope 2 emissions than on other sources. Spend less time identifying strategies to address small emission sources.
- **Stay organized.** For each emission reduction strategy under consideration, keep notes on the potential cost, emission reduction potential, timeline, and personnel needed to ensure success. These items will come in handy when selecting a final set of strategies.

- **Mitigate then offset.** Airports interviewed in the writing of this guidebook stressed the importance of mitigating emissions before offsetting. Interviewees noted that offsets lessen the interest of staff in finding innovative and forward-leaning mitigation strategies.
- **Review recent audit reports.** Airports routinely do energy efficiency or weatherization audits. These audits can provide valuable starting places for emission reduction strategies and often include the costs of the strategy.
- **Start with the most cost-effective strategies.** Early successes that reduce emissions and save money over a short period (e.g., energy-efficient light bulbs) should be the first initiatives undertaken. Starting with the obvious and easily implemented changes builds confidence in senior management and paves the way for more costly or complex strategies later.
- **Do not let the perfect be the enemy of the good.** Finally, think of the roadmap as a living document that can be updated over time. Develop an initial set of strategies with the intent to review and revise those strategies every few years.

## 4.1 Reduce Scope 1 and Scope 2 Emissions

This chapter provides guidance on identifying options for emissions reductions for Scope 1 and Scope 2. Because there are far too many potential strategies to include in this guidebook, the following text provides a high-level discussion of six strategies: energy efficiency, heating and cooling technologies, renewable electricity consumption, airport-owned and airport-operated vehicles, waste management, and other (Table 10).

For additional information on strategies, Table 11 highlights important resources and reports that provide practical guidance on emission reductions at airports.

Two of the more comprehensive resources of strategies for airport GHG emissions reduction are Appendix A of *ACRP Report 56* and the sustainable practices library on the Sustainable Aviation Guidance Alliance (SAGA) website. SAGA strategies include broad sustainability efforts in addition to emissions reduction. *ACRP Report 56* produced a handbook, a decision-support tool, and a set of 125 emissions reduction strategy factsheets with case examples to support airports in GHG emissions reductions. Though now several years old, many of the

**Table 10. Strategies to address Scope 1 and Scope 2 emissions.**

| Strategy Category | Description |
|---|---|
| **Energy efficiency** | • Energy efficiency improvements in airport-owned buildings |
| **Heating and cooling technologies** | • Upgrading of heating and cooling technologies in airport-owned buildings that lower airport energy consumption |
| **Renewable electricity consumption** | • Conversion of electricity to renewable sources, either through on-site renewables or off-site electricity purchases |
| **Airport-owned and airport-operated vehicles** | • Procurement of zero-emission vehicles for airport-owned fleet vehicles<br>• Use of low GHG fuels (e.g., biodiesel, renewable diesel) in airport-owned fleet vehicles<br>• Reduction in discretionary trips |
| **Waste management** | • Implementation of a composting program for food waste, etc.<br>• Implementation of a recycling program |
| **Other** | • Carbon sequestration (e.g., forest carbon management) |

**Table 11. Resources for strategies to address airport greenhouse gas emissions.**

| Resource | Stationary sources | Surface vehicle travel | Waste management | Electricity consumption | Aircraft emissions | Other | Offsets |
|---|---|---|---|---|---|---|---|
| *ACRP Synthesis 21: Airport Energy Efficiency and Cost Reduction* (2010). | ✓ | | | | | | |
| *ACRP Synthesis 42: Integrating Environmental Sustainability into Airport Contracts* (2013). | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *ACRP Report 56: Handbook for Considering Practical Greenhouse Gas Emission Reduction Strategies for Airports* (2011). | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *ACRP Report 78: Airport Ground Support Equipment (GSE): Emission Reduction Strategies, Inventory, and Tutorial* (2012). | | ✓ | | | | | |
| *ACRP Report 158: Deriving Benefits from Alternative Aircraft-Taxi Systems* (2016). | | | | | ✓ | | |
| Carbon Neutral Cities Alliance. (2015). Framework for Long-Term Deep Carbon Reduction Planning. | ✓ | ✓ | ✓ | ✓ | | | |
| Chicago Department of Aviation. (2012). Sustainable Airport Manual. | ✓ | ✓ | ✓ | ✓ | | ✓ | |
| Federal Aviation Administration. (2018). Technical Guidance for Evaluating Selected Solar Technologies on Airports. | ✓ | | | ✓ | | | |
| Federal Aviation Administration. (2012). Aviation Greenhouse Gas Emissions Reduction Plan. | | | | | ✓ | | |
| IATA. (2013). Technology Roadmap. | | | | | ✓ | | |
| Hall, Pavlenko, and Lutsey (2018). Beyond road vehicles: Survey of zero-emission technology options across the transport sector. | | | | | ✓ | | |
| Rocky Mountain Institute (2017b). Innovative Funding for Sustainable Aviation Fuel at U.S. Airports. | | | | | ✓ | | |
| Rocky Mountain Institute. (2017a). The Carbon-Free City Handbook. | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Sustainable Aviation Guidance Alliance. (2018). Sustainable Practices Library. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

compiled strategies are still relevant, and each factsheet contains helpful information about financial considerations, implementation considerations, and potential emissions impacts.

The research team also reviewed the availability of emissions calculators and several tools, including emissions inventory tools, project-specific emissions evaluation tools, and cost-benefits of emissions reduction strategies that exist to assist airports in emissions planning, as described in Table 12.

Resources for other types of institutions may also be useful, particularly for overlapping sectors like buildings or ground transportation. The Carbon Neutral Cities Alliance's Framework for Long-Term Deep Carbon Reduction Planning (2015) and Rocky Mountain Institute's Carbon-Free City Handbook (2017a) offer outlines and links to in-depth resources for strategies from leading-edge cities striving for zero emissions. Some strategies in these resources are about cities reducing their own emissions, and others are more policy focused to incentivize or mandate change among the broader public. These strategies may also be relevant as airports consider ways to cut Scope 3 emissions by guiding tenants and other third-party actors or exploring partnerships with the cities their airports serve.

## Energy Efficiency

Airports in search of emissions reduction strategies with low costs and short payback periods should first consider energy efficiency improvements to their existing facilities. In particular,

**Table 12. Sustainability tools to help reduce emissions at airports.**

| Year | Name | Author | Description |
|---|---|---|---|
| 2012 | Handbook for Evaluating Emissions and Costs of APUs and Alternative Systems | ESA (2012) | This report includes guidance on emissions estimations at airports, as well as an Airport Emissions Estimator Tool. |
| 2017 | ACERT Model | ACI (2017) | ACERT is an Excel-based tool that airports can use to calculate their own GHG emissions inventory. |
| 2017 | AEDT Model | FAA (2018b) | This software system models aircraft performance in space and time to estimate fuel use, emissions, noise, and air quality consequences for scenarios ranging from a single flight at an airport to global levels. |
| 2017 | GREET Model | Wang et al. (2017) | This full life-cycle model evaluates energy and emissions impacts of alternative transportation fuels and vehicle technologies. |
| 2017 | AFLEET Tool | Burnham (2017) | The AFLEET tool facilitates estimating petroleum use, GHG emissions, air pollutant emissions, and cost of ownership of light-duty and heavy-duty vehicles using simple spreadsheet inputs. |
| 2014 | MOVES2014b Model | EPA (2018) | This emissions modeling system estimates emissions for mobile sources at the national, county, and project levels for criteria air pollutants, GHGs, and air toxins. |
| 2017 | EMission FACtor (EMFAC) Model | CARB (2021) | This model is used to assess emissions from on-road vehicles including cars, trucks, and buses in California, and to support CARB's regulatory and air quality planning efforts. |
| 2018 | Electric Vehicle Emissions Calculator | UCS (2018) | This calculator compares emissions of plug-in hybrid electric and battery electric vehicles to gasoline-only vehicles, by ZIP code and the make, model, and year of a vehicle. |
| 2016 | Petroleum Reduction Planning Tool | DOE (2018) | This tool assists fleet managers in helping them to plan to reduce fossil fuel use and resulting GHG emissions. |

airports with older facilities are likely to find ample opportunities to increase energy efficiency. Table 13 is an example of how to organize the costs of energy efficiency strategies in one table to help with selection. Each measure in the table has a different payback period—some pay back very quickly and others take 10 years or more.

*ACRP Synthesis 21: Airport Energy Efficiency and Cost Reduction* documents low-cost energy efficiency practices implemented by airports and includes a comparison of the cost and payback period (Lau, Stromgren, and Green 2010). Airports can also refer to *ACRP Report 56* for a list of energy efficiency strategies, such as developing energy performance contracting

**Table 13. Lifecycle cost analysis for potential energy efficiency strategies.**

| Energy Saving Measure | Initial Cost | Annual Savings | Source of Annual Savings | Years to Payback | Net Present Value (20 Years) | Assumptions |
|---|---|---|---|---|---|---|
| Efficient lighting | $50,000 | $25,000 | 10 megawatt electricity savings, labor savings of $1,000 | 2 years | $305,310 | Cost of electricity and liquid fuels increases at 3% per year. Interest rate of 3%. Rebates for measures included. |
| Building wall and ceiling insulation | $50,000 | $5,000 | 600 gallons #2 fuel oil reduction, 3,000 cubic feet natural gas, 26 megawatt electricity | 10 years | $21,062 | |
| Window and door sealing | $40,000 | $4,000 | 500 gallons of #2 fuel oil, 2,000 cubic feet natural gas, 24 megawatt electricity | 10 years | $16,849 | |

*"The most sustainable energy is the energy you don't use."*

Denise Pronk, Program Manager, Corporate Responsibility, Royal Schiphol Group

partnerships, improving insulation of the airport building envelope, installing LED lighting for runways and taxiways, installing automated building control systems or variable frequency drives, and developing and marketing an energy conservation program for building users. Appendix A of *ACRP Report 56* details information about each strategy, including financial considerations, implementation considerations, potential impacts, potential limitations, and case study examples. The Sustainable Airport Manual developed by the Chicago Department of Aviation includes energy efficiency measures as part of its rating system, accompanied by case studies for certain measures. The case study that focuses on energy efficiency efforts at Los Angeles World Airports (LAWA) details that LAWA has upgraded 80% of its building air handling units with variable speed drives and 60% of computer servers to high efficiency servers and has retrofitted buildings with energy-efficient lighting (Chicago Department of Aviation 2012).

## Heating and Cooling Technologies

Heating, cooling, and ventilation can make up a substantial portion of Scope 1 emissions at most airports. In general, an airport should approach heating, cooling, and ventilation improvements by beginning with the end state and progressing toward the source (downstream to upstream). In other words, the first step should be to reduce heating or cooling demand through building envelope improvements. The next step should be to pursue retrofits, from the end points all the way back through the distribution system (e.g., fixing leaky ducting and adding zones). The final step would be to retrofit or replace the sources, such as purchasing a new furnace or converting a constant volume to a variable volume system. This sequencing is important for two reasons—the downstream improvements are typically cheaper and have a faster payback and the result of the downstream improvements informs subsequent measures upstream, such as by allowing the purchase of a smaller furnace/boiler.

### Airports Improving Efficiency of Heating and Cooling

Nantucket Memorial Airport installed efficient infrared heating units in their garages. SFO is in the process of getting a heat recovery chiller facility, which will help with efficiency and displace natural gas. Toronto Pearson International Airport is installing electric backup boilers for their heating system. These offer the airport a cleaner alternative to its existing natural gas boilers, adds redundancy to the system, and saves the airport money because it can switch to the electric boilers during off-peak hours when electricity is less costly.

After investing in insulation and other building envelope efficiency measures, an airport should consider addressing forced air duct leakage and possibly adding heating zones. It is relatively inexpensive to limit those losses by sealing leaks and, where feasible, insulating ducts. Zoned heating systems can save energy if parts of an airport building have different temperature requirements and can be closed off from one another. A zoned system can provide a different amount of heat to each zone, depending on its usage. A building can be zoned in several ways. Some multizone systems have only one furnace/boiler and use electrically controlled dampers, which can open or close depending on the heating needs of different zones. Other systems have separate furnaces/boilers for each zone.

In the final step of source replacement, airports should consider switching to cogeneration (also known as combined heat and power or CHP), which uses an engine to generate electricity and recovers the waste heat for use. Trigeneration (also known as combined cooling, heat and power or CCHP) is the simultaneous production of electricity, heat, and cooling from a single energy source. Similar to CHP, the waste heat by-product that results from electricity generation is captured and used for heating or cooling. Cogeneration and trigeneration systems are typically more efficient than purchased electricity or fuel because they use waste

heat and avoid transmission losses. Canberra International Airport in Australia installed a trigeneration system to provide power for four office buildings, resulting in the reduction of more than 1,000 tons of $CO_2$ emissions and $160,000 per year in energy costs (CDM 2011).

Ground-source, or geothermal, systems can be used either to heat water or to heat or cool indoor space. These systems use the ground as a heat source during the winter and a heat sink during the summer because ground temperatures remain relatively constant. Geothermal systems can significantly reduce the amount of electricity or fuel needed to heat or cool a building, thus reducing associated GHG emissions. Nantucket Memorial Airport installed a geothermal heating and air conditioning system that allowed the airport to replace two oil-burning furnaces and thus decrease GHG emissions.

*ACRP Report 56* documents additional strategies to consider for clean heating and cooling, including solar desiccant air conditioning systems, on-site biomass energy systems, sewer heat recovery systems, and using natural bodies of water for cooling. Airports are encouraged to review the description and considerations included for each strategy to determine which ones may be feasible for their facilities.

## Renewable Electricity Consumption

Installation of on-site renewable electricity generation is increasingly attractive, given the declining costs and added protection against short-term blackouts or long-term utility outages. The most common on-site renewable electricity systems are solar powered, although on-site biomass energy production, building-mounted wind turbines, geothermal heating and cooling systems, or geothermal snow and ice melting systems are also potential options at airports. Finally, waste-to-energy systems and gas produced from local landfills are other ways to recycle waste and produce valuable low-carbon electricity (CDM 2011).

Purchase of off-site renewable electricity is another option for lowering Scope 2 emissions. Depending on its location, the airport may be able to buy a green pricing product or green marketing product from the electricity provider. The airport typically pays a small premium in exchange for electricity generated from renewable power resources. The premium covers the increased costs incurred by the power provider (i.e., electric utility, when adding green power to its power generation mix).[3]

Another option is to develop power purchase agreements (PPAs), either for renewable energy generated on site or in some cases off site (requiring certification and issuance of renewable energy credits or RECs). In 2018, the FAA updated its in-depth guidebook for airport solar development, documenting case studies from the 15 airports that have invested in solar technologies. It also provided guidance on key issues for airports to navigate including glare and reflectivity issues that might cause vision loss to pilots arriving or departing, or to air traffic control personnel. Another issue detailed in the solar guide is that electromagnetic interference with radar systems may create false signals and communications interference (FAA 2018a). Other key sources of guidance for airports on renewable energy strategies include *ACRP Report 56*, *ACRP Research Report 197: Guidebook for Developing a Comprehensive Renewable Resources Strategy* (Shaw et al. 2019), and *ACRP Research Report 228: Airport Microgrid Implementation Toolkit* (Klauber et al. 2021).

### Electricity Grid Mix Considerations

When evaluating renewable electricity projects, it is vital to consider the electricity grid mix. If the grid mix includes large amounts of electricity generated by burning coal, then projects improving efficiency or switching to renewable electricity will have an outsized impact compared to if the grid mix were heavily produced through emission-free hydropower. For example, in Montreal where electricity is heavily generated via hydropower and thus nearly emission-free, switching heating and cooling to electricity makes more sense than in areas with a coal-intensive grid.

[3] In competitive markets, airports can choose to purchase green marketing products from providers other than their local utility. In regulated markets, airports may be able to buy a green pricing product from their local utility.

### Airport Fleet Vehicles

Airport fleet vehicles occupy a unique niche among all vehicle fleets, with hundreds or even thousands of diverse vehicles. Emissions inventories suggest fleet vehicles are one of the primary sources of emissions at airports. For example, at the Philadelphia (PHL), Los Angeles (LAX), and Minneapolis-St. Paul (MSP) International Airports, fleet vehicles account for 38%, 43%, and 45% of Scope 1 emissions, respectively. Besides helping reduce emissions, alternative fuels can help airports manage fuel costs, reduce petroleum dependence, increase energy security, improve public image, and potentially reduce maintenance efforts.

## Airport-Owned and Airport-Operated Vehicles

Airport-owned or operated cars, trucks, and buses are a major Scope 1 emission source for most airports. These vehicles (and their emissions) fall under the control of the airport and are different from Scope 3-related vehicles such as airline-owned ground support equipment, externally owned ground transportation vehicles (e.g., taxis, limousines, city transit buses), and personal vehicles. At many airports, airport-owned and operated vehicles can number in the hundreds or even thousands and include work trucks, office pool vehicles, emergency service vehicles, security vehicles, and shuttle buses (e.g., between terminals).

Options to lower emissions from these vehicles include swapping fuels to a less-carbon intensive fuel (e.g., fleet electrification), reducing the amount of vehicle travel, or shifting to more efficient vehicles (i.e., towards vehicles with lower fuel economy). As described in *ACRP Synthesis 85: Alternative Fuels in Airport Fleets* (Morrison, Fordham, and Fields 2017), fleet electrification is emerging as the preferred strategy in recent years due to the financial savings and elimination of all tailpipe emissions. However, other fuel-swapping strategies are common, including use of renewable natural gas, conventional natural gas, biodiesel, and renewable diesel.

During development of the airport emissions roadmap, airport staff should work closely with the fleet manager to answer the following questions:

1. What is the current vehicle composition (i.e., how many sedans, pickup trucks, buses, etc.)?
2. Does the airport-owned or operated fleet have an existing fleet sustainability goal (e.g., 25% of vehicles are electric by 2025)?
3. How many new vehicles are procured and retired each year (thus, informing the potential rate of conversion)?
4. Are there any restrictions that prevent the use of certain fuels (e.g., contractual items, safety codes)?

Answers to these questions help inform the potential timing and impact of emission reductions from fleet vehicles. For purposes of the emissions roadmap, a rough estimate on emissions reduction potential may be sufficient. However, prior to actually converting vehicles to a different fuel or power train, fleet managers should conduct a detailed suitability study that examines costs, vehicle options, routes, fueling locations, and operational feasibility. This type of study helps fleet operators prioritize vehicles for replacement, develop a fleet conversion schedule, and understand infrastructure requirements.

## Waste Management

As waste materials decay in landfills or get burned in incinerators, they release GHGs. Airports can adopt waste management tactics to reduce emissions from the waste stream, including recycling, composting, waste reduction efforts, and improvements to wastewater treatment facilities, where applicable. Strategies may include a solid waste management plan, a waste reduction and recycling program, separating and composting food waste, and others that can help reduce methane ($CH_4$) and other GHGs from the waste stream (CDM 2011).

As a first step, airports should focus on source reduction and reuse, since generating fewer waste materials reduces emissions associated with waste collection, transportation, and disposal. Source reduction and reuse avoid emissions regardless of whether materials would have

been processed for disposal or recycling. In addition to materials management, airports with wastewater treatment facilities have opportunities to reduce emissions by converting output gases to usable energy. Airport wastewater treatment systems that have anaerobic digesters to treat de-icing fluids may use the methane generated from the digesters to produce heat or electricity instead of venting the methane to the atmosphere. The Albany Airport in New York has implemented such a system (CDM 2011). Airports can apply this waste-to-energy concept to solid waste materials too. Gatwick Airport constructed an on-site materials recycling facility which increases the airport's reuse and recycling rate and converts waste to low-carbon energy (Gatwick 2016). In the future, airports may be able to supply their solid waste as jet fuel feedstock, partnering with companies that apply a Fischer-Tropsch technology to convert this feedstock to jet fuel. Additional information regarding waste management best practices is available in *ACRP Synthesis 92: Airport Waste Management and Recycling Practices* (Turner 2018), *ACRP Report 100* (Cascadia Consulting Group 2014), *Recycling, Reuse, and Waste Reduction at Airports—A Synthesis Document* (FAA 2013) and *Guidance on Airport Recycling, Reuse, and Waste Reduction* (FAA 2014).

## Other

Other emissions sources at airports might include construction activities, firefighting training exercises, refrigerant leaks, and others. Even relatively small emission quantities of GHGs like methane and refrigerants have significant outsized climate impacts due to their higher global warming potentials—about 2,000 times higher in the case of common refrigerants—compared to $CO_2$ (CARB 2019b). Construction activities result in GHG emissions through many of the same mechanisms as discussed above: fossil fuel combustion by construction vehicles, processing and disposal of construction waste, and lighting and other energy uses.

Airports can reduce construction emissions through policies that require the use of low-emission construction vehicles and equipment, recycling and reuse of construction materials, and use of energy efficient lighting during the construction process, for example (CDM 2011). As part of its Chicago O'Hare Modernization Program (OMP), the Chicago Department of Aviation (CDA) implemented tailpipe emissions standards for construction equipment that were later adopted as city-wide policy. CDA incorporated the standards into construction bid documents and established an enforcement mechanism by requiring emissions documentation to be attached to invoices prior to approval. Even though CDA was not mandated to, it required the use of ultra-low sulfur diesel (ULSD) for certain vehicles when the OMP began because air quality was a priority for such a large project. These policies not only reduced GHG emissions and criteria pollutants but also may have bolstered the market for ULSD (Chicago Department of Aviation 2012).

Firefighting exercises at airports typically involve firefighters training in a live-fire environment. These training exercises result in GHG emissions from fire suppression chemicals. Airports are encouraged to work with training staff to optimally plan exercises such that the minimum amount of fuel is used while still providing necessary training. The EPA, in partnership with four major associations representing the fire protection industry, developed a voluntary code of practice to minimize emissions of two GHGs used as fire protection agents: hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). The emissions reduction strategies in the code of practice include adopting maintenance practices that reduce leakage as much as technically feasible, limiting discharge for system testing to what is essential for performance requirements or required by regulation, and ensuring that technicians who handle equipment containing HFCs and PFCs are trained to minimize emissions.

Hydrochlorofluorocarbons (HCFCs) and HFCs and are two GHGs used in refrigeration and air conditioning systems. HFCs and HCFCs are emitted during operation, repair, and disposal, unless recovered, recycled, and ultimately destroyed (EPA 2016c). Airports can take several

steps to minimize the release of these GHGs, including utilizing natural refrigerants where possible, installing intelligent fault diagnosis systems to detect leaks, using vapor compression heat pumps, and installing microchannel components and heat exchangers to reduce the number of refrigerants used. Guidance for each of these strategies can be found in *ACRP Report 56*.

## 4.2 Offset Emissions

A carbon offset program "reduces, avoids, or sequesters GHGs in order to compensate for emissions occurring elsewhere" (Ritte 2011). These programs can be made up of myriad project types, from supporting forestry expansion to renewable energy. Often there are markets where entities can trade accredited offsets, essentially allowing them to purchase the right to say they reduced emissions without actually having undertaken the emissions reduction project. Being accredited is the official acknowledgement that 1 ton of $CO_2$ emissions were displaced. Some regulating bodies use offsets as a way to regulate carbon emissions (as opposed to a flat tax on carbon, or other approaches). One such example of this is CORSIA (discussed in Section 1.2), which has established voluntary goals for 2021–2026 and mandatory offset minimums for 2027–2035 (ICCT 2017).

Airports can adopt carbon offset projects voluntarily or in response to compliance measures. Compliance-based carbon reduction programs, such as the Regional Greenhouse Gas Initiative (RGGI) in North America, are regulated by mandatory international, national, or regional entities to require participants to reduce or offset $CO_2$ emissions *ACRP Report 57: The Carbon Market: A Primer for Airports* (Ritter, Bertelsen, and Hazeman 2011). Demand for compliance-based carbon offsets is created by a regulatory instrument (CORE 2019). Carbon offset market participation and demand can be also driven voluntarily by national, regional, organizational, or individual interest in $CO_2$ emissions reductions, though there are no rules or regulations established for voluntary offset trading (CORE 2019).

ACA is one of several organizations that acknowledge airports that reduce their emissions of carbon. In December 2018, the organization published Issue 1 of the Offsetting Guidance Document to provide airport users with a concise overview of the global carbon offsetting management accreditation program, guidance on offsetting options, key offsetting quality criteria and recommendations, and practical and applicable support (ACA 2018b). The document includes term definitions, examples of carbon offset project types, and GHG mitigation actions ranked by level of confidence, procurement guidelines, a list of independently verified offset programs, and more. Although there is a cost to becoming ACA-certified, airports can use the resources and framework without obtaining the official certification. This can be a great way to get started and realize some of the benefits of zero- or low-emissions planning for any airports that are financially or otherwise resource constrained.

According to the ACA offsetting guidance, several criteria may be used to evaluate the quality of a carbon offset program (ACA 2018b). The criteria can be separated into mandatory and optional categories. Mandatory criteria include *additionality* (i.e., the emissions reductions would not have occurred in the absence of the offset) and *permanence* (i.e., the offset is not reversible). Most offset programs are geared toward airline emissions rather than airport emissions. Airports interviewed for this guidebook typically purchase offsets from local organizations so airport funds stay within the jurisdiction. Other major offset programs are described below, some of which are only for offsetting airline travel.

### Certified Emissions Reduction

A certified emissions reduction (CER) is a certificate issued by the United Nations to member nations for preventing 1 ton of $CO_2$ emissions. United Nations Clean Development Mechanism

(CDM) allows Annex I Parties, countries with developed or traditional economies, to purchase or trade CERs to help them achieve emissions reduction targets under the Kyoto Protocol while supporting sustainable development in developing countries. For projects to be CDM-accredited and eligible for CERs, they must create real, measurable, and long-term benefits to climate change mitigation and produce additional emissions reductions that would not have otherwise occurred. Companies can also purchase CERs to contribute toward their own emissions reduction targets under mandatory emissions trading schemes, such as the European Union Emissions Trading Scheme, or voluntary schemes.

### Offsets and Revenue Diversion

FAA considers use of airport revenue for costs associated with airport carbon accreditation programs, including the voluntary purchase of carbon offsets, within the boundaries of permitted operational costs as discussed in the Revenue Use Policy (64 Fed. Reg. 7696, February 16, 1999). When these costs are directly and substantially related to the airport, (i.e., the carbon offsets purchased are based on the carbon generated by the airport) the benefit of the offset accrues directly to the airport sponsor.

### Proprietary Verified Emissions Reduction

Unlike CERs and EUAs, verified emissions reductions (VERs) are exchanged in the voluntary market, which function outside and in parallel of the regulatory market. VERs can be created under CDM or under other standards (e.g., Gold Standard, Voluntary Carbon Standard, VER+) operating in the voluntary market. CERs can be accepted in both the regulatory and voluntary market, but VERs are accepted only in the voluntary market. Although the voluntary market is smaller and does not have established rules and regulations, its lower development and transaction costs enable entities to experiment with new methodologies and technologies under small projects.

### The Good Traveler

The Good Traveler is a nonprofit, established by and for airports, which allows passengers to mitigate the environmental impact of their flight through the purchase of a carbon offset. Through the purchase of a $2.00 Certified Carbon Offset, a passenger offsets the carbon released in 1,000 miles of flying (or 400 miles of driving). Funds generated through The Good Traveler support projects that offset carbon, including renewable energy, landfill carbon capture and reuse, and waste composting, among others.

## 4.3 Reduce Scope 3 Emissions

Scope 3 emissions are those under the control of tenants, passengers, employees, or other organizations at the airports and are typically the largest (by far) category of emissions at an airport. Addressing Scope 3 emissions can be challenging for a number of reasons. First, it can be unclear which entity is responsible for the emissions. Additionally, emission reduction programs require coordination and cooperation with third parties and/or tenants, which becomes more arduous as the number of partners increase. Partners may not be aligned toward the same social goals as the airport and may see any effort to reduce Scope 3 as an infringement.

Despite the various challenges, airports are increasingly finding creative and novel approaches for addressing Scope 3 emissions. In many cases where an airport cannot directly mandate emission reductions, it can encourage the reductions through positive reinforcement and awards. Simply being prepared and available to assist when tenants want to pursue an emissions reduction strategy can be an option, which is how SFO is approaching SAF. Similarly, some airports have sought to educate tenants by paying for consultants or energy analysts to come and offer free evaluations to show the tenants how they could save money from efficiency measures that reduce emissions. Another possible strategy is to reduce administrative and logistical barriers

to support emissions reduction (such as installing electric vehicle chargers). A specific example of a Scope 3 emission reduction program at Hong Kong International Airport is shown in the box and Figure 13.

## Airport Policy Measures

Airports can implement policies to encourage airlines and other tenants to adopt cleaner technologies and practices. For example, airport contracts for design and construction, concessions and tenant lease agreements, and janitorial service contracts are an opportunity to drive airport environmental practices. *ACRP Synthesis 42: Integrating Environmental Sustainability into Airport Contracts* provides an overview of contract-based emissions reduction options (Haseman 2013). Green leases, as defined in *Green Lease Guide: A Guide for Landlords and Tenants to Collaborate on Energy Efficiency and Sustainable Practices* by Building Owners and Managers Association International, allow tenants and airports to come to an agreement that shares the cost of any improvements, allowing both parties to benefit by seeing reduced operating costs (Jossi 2018). Green leases with tenants are described in Section 5.3.

### Airport Authority Hong Kong Data Tracking and Sharing Platform

In seeking to reduce emissions not directly under its control, the Hong Kong International Airport faces the challenge of having 73,000 workers who are not under the direct authority of the airport. Furthermore, the airport has a large amount of non-aeronautical activity on the airport—40% of emissions are from airport operations and 60% are large on-airport business partners. To help address these challenges, in 2011, Airport Authority Hong Kong (AAHK) built a carbon audit system that enables it to track, understand, set a reduction target, and report on "airport-wide" emissions of 53 airport business partners (ABPs) (Figure 13). Each company has its own password-protected space on the platform, and AAHK discloses only the collective performance of the whole airport community. AAHK provides the software for free and offers free training. Participating ABPs upload their data every 6 months. According to airport staff, this system builds trust with the partners and encourages reductions in Scope 3 emissions.

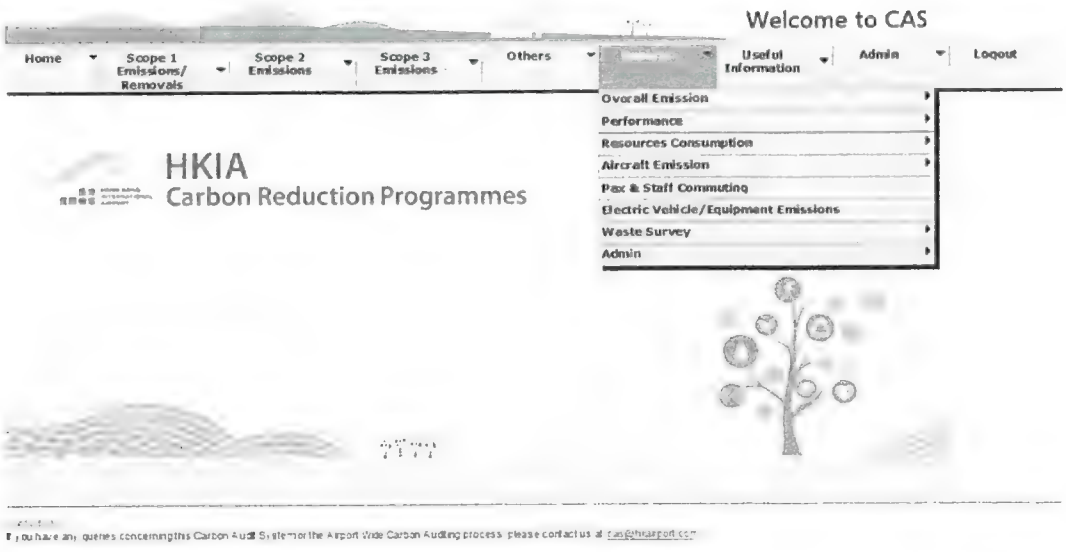


*Figure 13. Airport Authority Hong Kong data tracking and sharing platform.*

A memorandum of agreement (MOA) can be received more favorably by tenants than a green lease (see Section 5.3). MOAs are often viewed as business contracts by tenant legal departments, who are not always receptive to including emissions goals. When considering how to encourage tenants to reduce emissions, airports can enter into an MOA, allowing tenants greater flexibility on timing and amendments. This option may be especially attractive in a weak economic environment when tenants value extra flexibility outside of a lease agreement.

**Airports Reducing GSE Emissions**

Through the "EV100" initiative, Hong Kong International Airport (AAHK) is one of many airports beginning to implement electrified GSE. In 2018, AAHK had 240 pieces of electric GSE equipment and is continuing to expand this electrified fleet. Indira Ghandi International Airport is employing TaxiBots—electric semi-robotic, pilot-controlled towing tractors—in an effort to reduce emissions from GSE while taxiing planes to the runway.

## Ground Support Equipment

*ACRP Report 78: Airport Ground Support Equipment (GSE): Emissions Reduction Strategies, Inventory, and Tutorial* documents the various types of ground support equipment (GSE), functions, suppliers, and ultimately strategies to reduce emissions from these vehicles (CMD Federal Programs Corporation 2012). Emissions from GSE can create more localized air quality impacts so these have been a concern of airport stakeholders and are subject to federal and state emissions regulations. One set of strategies includes terminal gate electrification projects, such as replacing diesel-powered air conditioning units with fixed pre-conditioned air (PCA) systems or minimizing diesel-powered ground power units (GPUs) and aircraft start units (ASU) use at the gate through providing 400 Hz electrical systems.

Other strategies encourage converting GSE to alternative-fuel vehicles and reducing extensive idling common for some airports. Airports could undertake strategies to encourage or mandate cleaner GSE operations by airlines or other tenants, including through use of emissions fees and tenant lease agreements, though challenges are often associated with implementing such strategies.

Airports should be aware of space or infrastructure constraints that affect implementing GSE emissions reduction strategies. For example, some airports are space-constrained on the ramp and find it challenging to install enough chargers to fully electrify the GSE operation. Equipment typically must charge overnight and remain parked near the chargers. Highly congested airports such as Seattle-Tacoma may especially need to consider these constraints. Energy supply can also be an issue for older facilities, requiring the local utility to potentially upgrade substations feeding the airport.

In recent years, there has been an increase in the viability of electrification of GSE, sometimes referred to as eGSE, due to the lowered emissions from electricity supplies in most areas of the United States as well as the improvement of electric vehicle technology and reduction in costs.

## Ground Access Vehicles

Ground access vehicles (GAVs) refer to landside ground transportation at an airport and include vehicles used by and for airline passengers, airport employees, airline or airport tenants, and freight delivery—as discussed in *ACRP Research Report 180: Guidebook for Quantifying Airport Ground Access Vehicle Activity for Emissions Modeling* (Kenney 2017). These vehicles can include private vehicles, rental cars, taxis, transportation network companies (TNCs), door-to-door vans, hotel shuttles, public transport, service and delivery vehicles, and air cargo vehicles. Strategies to reduce emissions from GAVs include improved public transit, walking, and bicycle connections; consolidated rental car facilities; incentives for employees

**San Diego International Airport's Shuttle, Taxi, and TNC Emissions Reduction Program**

San Diego International Airport began with requiring emissions reductions from taxi and shuttle fleets accessing the airport in 2012. The fleets report on a monthly basis (with the make and model of vehicle, and other information) and emissions intensities are calculated. In subsequent years, TNCs have become part of the program too. In 2018, all TNCs were meeting the goal.

to take public transit, walk, or bicycle to work; incentives for passengers, taxis, limousines, TNCs, or employees arriving in zero emission vehicles; conversion of vehicles like airport shuttles to alternative fuel vehicles; and avoiding construction of new parking capacity (Chicago Department of Aviation 2012). Airports can also encourage private ground transportation operators to implement strategies to decrease the number of empty rides, or trips without passengers, that drivers take. *ACRP Synthesis 89: Clean Vehicles, Fuels, and Practices for Airport Private Ground Transportation Providers* provides more detailed guidance on several of these policy options (Kolpakov, Sipiora, Huss 2018).

One example of a creative program addressing GAV emissions is at Amsterdam Airport Schiphol. The airport targeted taxi electrification as a key goal and by 2018 was served with 167 Tesla Model S taxis. The airport has heard positive reviews from customers about the comfort and from the operators because of reduced maintenance costs. Additionally, although the airport has little influence on community transit agencies, it managed to sway decision-makers and help obtain a zero-emission requirement for the community buses. As of 2018, these adjacent communities operate 100 electric buses. The airport believes that having adopted its own electric buses early on helped prove the viability of electric buses to adjacent communities.

## Aircraft Emissions Strategies

The single largest source of emissions at airports is aircraft. Aircraft design and airline operational improvements have dramatically reduced fuel burn since the introduction of jet engines over 50 years ago. On a per-passenger basis, emissions are more than 80% lower than in the 1960s. However, total GHG emissions from aircraft are growing due to demand. The following discusses three broad categories of mitigation options for aircraft emissions: Taxiing, Landing, Takeoff; Sustainable Aviation Fuel; and Aircraft Technology.

### *Taxiing, Landing, Takeoff*

Though airports do not have direct control of aircraft usage, they can influence industry emissions in several ways. FAA estimates that approximately 5% of aircraft emissions occur while aircrafts are on the ground or operating below 3,000 feet (FAA 2015). Strategies to reduce aircraft emissions during these phases include reducing takeoff and climb thrust, increasing efficiency during airport taxiing such as through reducing engine use, improving operational efficiency through programs like the FAA's Next Generation Air Transportation System (NextGen), and replacing main engines for taxiing with systems such as alternative aircraft-taxiing systems or equipment similar to aircraft pushback tractors. Single-engine taxi is the most prevalent approach to reducing taxiing emissions.

**General Aviation Leadership on Scope 3**

Los Angeles Van Nuys Airport, a general aviation facility, has numerous projects to lower Scope 3 emissions. For example, the airport has six tenant solar projects underway. Additionally, in 2019, the airport became the first general aviation airport to supply sustainable alternative jet fuel to aircraft operators (LAWA 2019).

A review of alternative taxiing systems highlighted the potential for several technology and efficiency strategies to reduce GHGs and criteria pollutants, particularly electrified technologies, yet also noted that the operational and fiscal challenges airlines and airports may face in implementing such strategies (Fordam et al. 2016). The technologies studied include dispatch taxiing (e.g., using existing aircraft pushback tractor technology), semi-robotic dispatch taxiing (i.e., similar to a

pushback tractor but using a hybrid external large tractor developed specifically for taxiing), nose-wheel-mounted alternative aircraft-taxiing systems, and main landing gear alternative aircraft-taxiing systems. In the long run, airports can also incorporate more efficient design into airfield and runway layout to reduce congestion and delays (CDM 2011).

### *Sustainable Aviation Fuel*

The aviation industry has jointly made a commitment to reduce GHGs through efficiency measures and voluntarily submitted to a carbon market to allow for carbon neutral growth starting in 2020 through CORSIA. The aviation industry is targeting a 50% reduction in GHGs by 2050 relative to 2005 levels. Use of sustainable aviation fuel (SAF) is an attractive strategy for reducing these emissions.

Drop-in SAF can be used safely in commercial aircraft without modification and produced sustainably with renewable feedstock, including used cooking oil, tallow, energy crops, agricultural and forestry residues, and municipal waste (Rocky Mountain Institute 2017). For many SAFs, the fuel is burned with substantial reductions in criteria pollutants such as PM and $SO_x$ as well as modest reductions in unburned hydrocarbons. In recent years there have been several advances toward commercially viable SAF, including the inauguration of the first commercial-scale SAF refinery in the United States, the enabling of credits for SAF under government incentive programs at the federal (RFS2) and state (LCFS) levels, and the approval of five different fuel production pathways through the ASTM D7566 specification of synthetic turbine fuels.

Though interest is growing among airports and airlines to move beyond just demonstration projects to incorporation into daily operations, several related barriers have kept SAF from penetrating the market. These barriers include low production volume, high prices compared to conventional jet fuel, and infrastructure costs for transporting and blending. One production pathway depends on fats, oils, and greases (i.e., lipids), but a potential challenge is their limited supply. This energy source is likely to become more expensive in the future as supply remains stable yet demand grows, and therefore lipid prices may increase.

There is currently an insufficient supply of SAF to significantly reduce industry emissions. However, several biofuel producers are working to ramp up production. As of 2018, several production facilities were under construction. According to CAAFI, planned increase in the production of SAF is modest but meaningful and a vital step toward the viability of the fuel. This increase in production is expected to further open capital markets.

The Port of Seattle has set a goal to power every flight fueled at Seattle-Tacoma International Airport (SEA) with at least a 10% blend of SAF by 2028 (Port of Seattle 2019). In 2016, the airport commissioned a study to assess the feasibility of fueling infrastructure sufficient to reach that goal, which would enable receipt, blending, storage, and delivery of an 80% jet fuel, 20% biofuel blend. The study highlighted the complex supply chain and infrastructure challenges associated with biofuels as well as the importance of partnerships to enable aircraft emissions reduction strategies.

### *Aircraft Technology*

In 2013, the International Air Transport Association (IATA) released a Technology Roadmap to identify possible technological improvements to the engine and the airframe (such as aerodynamics, lightweight materials and structures, equipment systems) to support meeting the goal set by IATA, global associations of aerospace manufacturers, airports, and other partners of reducing aviation emissions by 50% by 2050 (IATA 2013). Through modeling, researchers estimated that existing technological improvements could increase fuel efficiency by 30% for the aircraft generation after 2020, but that more advanced technologies would be necessary to meet

the 50% by 2050 goal. The roadmap also discusses emerging but not yet commercialized technologies, such as new wing designs to enable reduced weight, formation flight, battery-powered aircraft, and aircraft fuel from solar energy.

Through FAA's Continuous Lower Energy, Emissions, and Noise (CLEEN) program and NASA's Environmentally Responsible Aviation (ERA) program, the U.S. government has been investing in research and development in collaboration with airlines to improve aviation design and, at least initially, to meet the Obama administration's goal of achieving carbon neutral growth in U.S. aviation by 2020. CLEEN had a target to reduce fuel burn by 25% by 2015 and ERA to reduce fuel burn by 50% by 2020.

Electric aircraft can offer carbon-free air travel, zero criteria pollutant emissions, reduced noise, reduced operating costs, less frequent aircraft maintenance, avoidance of safety and supply chain issues associated with liquid fuels, and possible revenue generation from charging fees. Manufacturers such as Airbus have been working to develop electric aircraft models that could serve short haul flights as well as a newer concept for intra-urban air taxis. Norway is aiming to electrify all short-haul flights by 2040. Avinor, which owns and operates most of Norway's airports, commissioned a feasibility study that concluded that battery-powered electric aircraft could serve more than 20 short routes in Norway as of the date of this publication and will be able to accommodate flights of more than 500 kilometers, or 300 miles, by 2028–2030 (Reimers 2018).

## 4.4 Select Strategies

Unlike Sections 4.1, 4.2, and 4.3, which focus on GHG mitigation strategies, this section presents methods for visualizing, comparing, and ultimately selecting the set of strategies to be included in the roadmap. This process is an art, not a science. Each airport will have unique considerations when selecting its strategies. The visualization methods below are meant to help with this selection process. Although time-intensive, producing one or more of these visualizations leads to more fruitful discussions with senior management and could become central graphics in the roadmap.

Figure 14 is an example of a wedge stabilization chart that shows the contribution to emissions reduction of each strategy over time. The top edge of the graphic extending up and to the right

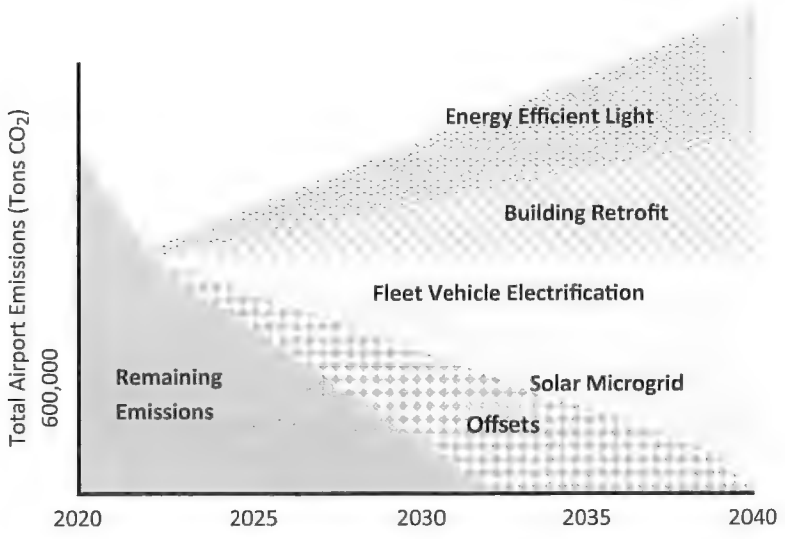


***Figure 14. Wedge stabilization chart.***

represents the path of emissions in a Reference or Business-as-Usual scenario. Each strategy contributes to a reduction from that upper line. In the figure, by 2035 the remaining emissions are zero. A wedge stabilization chart is a useful tool for visualizing the various impacts that strategies have on current GHG emissions.

Figure 15 is an example of a waterfall chart which shows how multiple emissions mitigation strategies reduce emissions to the level of an emissions goal. Waterfall charts show similar insights as wedge stabilization diagrams, except they do not show emissions reductions over time and are capable of greater detail in showing various emissions reduction categories (e.g., the stacked columns provide an extra layer of detail).

Another method for showing or comparing various emissions reduction strategies is a marginal abatement cost (MAC) curve. MAC curves are useful tools for presenting carbon emissions reduction costs per ton of emissions mitigated. MAC curves, such as the example in Figure 16, are comprised of discrete "blocks" that represent an individual carbon abatement measure. Blocks are organized by the marginal economic cost of emissions abatement ($/tCO$_2$). The widths of each block reflect the amount of potential carbon emissions abatement (tCO$_2$). The graph is ordered left to right from the lowest cost to the highest cost opportunities. Those opportunities that appear below the horizontal axis offer the potential for financial savings even after the upfront costs of capturing them have been factored in.

A final method for visually comparing two or more emissions mitigation strategies is through a qualitative diagram that compares strategies across different objectives. Table 14 is an example of a comparison chart that uses Harvey balls to convey the relative score. Similarly, heat maps or simple up/down/left/right arrows help quickly turn a table with numeric values into a visually appealing diagram for the reader.

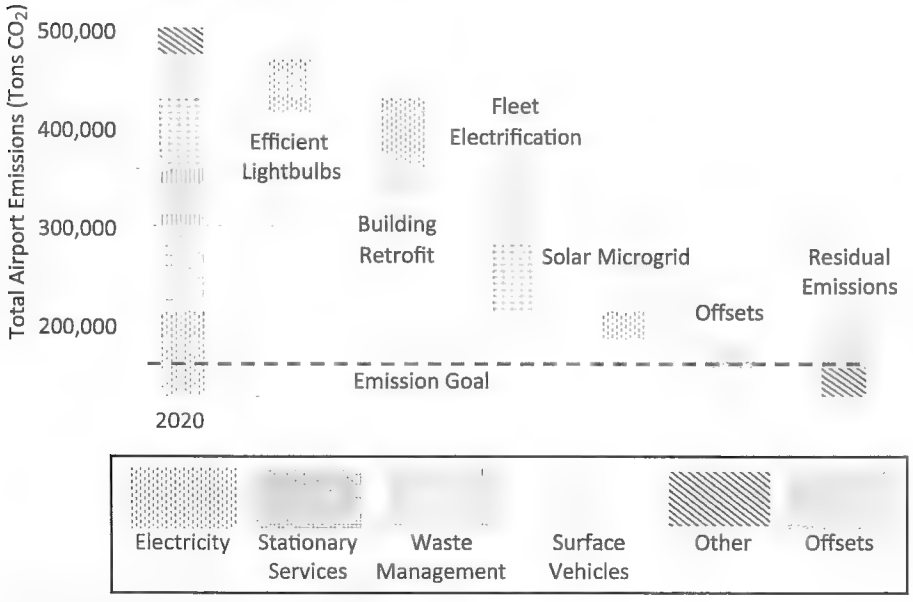


***Figure 15. Waterfall chart.***

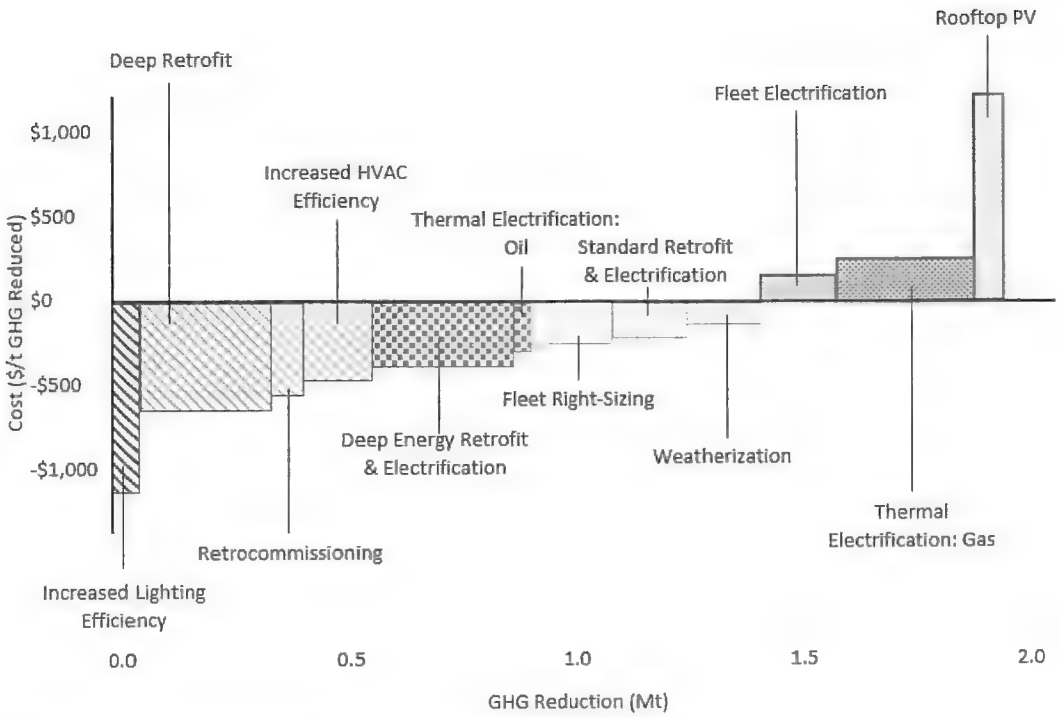


***Figure 16. Marginal abatement cost curve.***

**Table 14. Qualitative evaluation using Harvey balls.**

| Evaluation Criteria | Energy Efficient Light Bulbs | Building Retrofit | Fleet Vehicle Electrification | Solar Microgrid |
|---|---|---|---|---|
| GHG Reduction Total | ◓ | ◓ | ● | ● |
| $ per Ton of GHG Mitigated | ◒ | ○ | ● | ● |
| Total Cost of Ownership | ● | ○ | ◒ | ◒ |
| Ability to Reduce Criteria Pollutants | ◒ | ○ | ◓ | ◓ |
| Technology Readiness | ○ | ◓ | ◓ | ○ |
| Minimal Infrastructure Requirement | ● | ◒ | ◒ | ◒ |
| Administrative Burden | ● | ○ | ◒ | ◒ |
| Training Burden | ● | ○ | ○ | ○ |

● Excellent ◓ Good ○ Satisfactory ◒ Poor ⊗ Unacceptable

CHAPTER 5

# Funding Opportunities and Mechanisms

Airports have a range of funding mechanisms and sources at their disposal for emissions reduction projects. Each funding mechanisms or source has specific requirements for on-going airport administrative burden. This chapter provides an overview of each mechanism and source, as well as advantages and drawbacks referred to as pros and cons. Airports can also consult with the recommended resources provided. Chapter 5 divides funding mechanisms and sources into three categories: public, airport-based, and third-party (Figure 17).

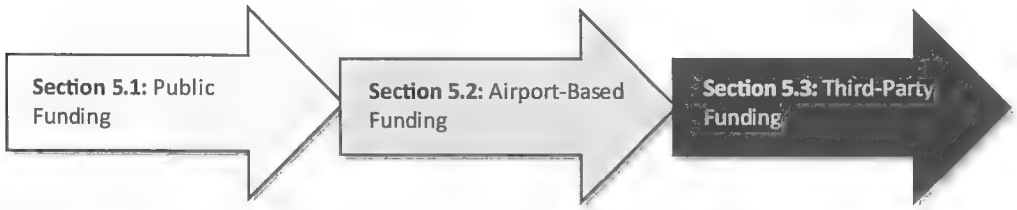


*Figure 17. Categories of funding opportunities and mechanisms.*

## 5.1 Public Funding

The public funding section offers a range of options that airports can use to generate funding from federal and state grants. Some grant options may compete for conventional airport infrastructure projects. Public funding programs can change over time. The information presented below is representative of the funding sources available at the time of publication in 2021. Please refer to agency websites for the full and latest details on each of these funding sources.

### Voluntary Airport Lower Emissions Program

FAA provides grants to airports specifically targeted at improving air quality in EPA-designated nonattainment areas (FAA 2017b). Grants cover a portion of the cost to install equipment that reduces aircraft auxiliary power usage while aircraft are parked at the gate. Using ground power, airlines can connect with electricity from the terminal and avoid using jet fuel for lighting and other systems. Airports can also supply cooling or heat to the cabin via flexible ducting carrying preconditioned air. Combining both of these measures can reduce 1% of emissions from the total flight.

Voluntary Airport Lower Emissions (VALE) grants also cover direct emissions reductions from operations and actions that reduce fuel burn on the airport (FAA 2017b). Eligible projects include electrification of GSE, geothermal systems for building heat and cooling, solar thermal,

and installation of a fuel hydrant system for aircraft. Alternative fuel infrastructure for non-GSE vehicles, which includes electricity and hydrogen, also offer potentially viable projects. A document available for download at FAA's website shows the purpose of VALE grants that have been awarded to airports and other details such as the amount of each award.

**Pros**

- Grant support can be significant for individual projects.
- Magnitude of emissions savings versus cost is favorable.

**Cons**

- Airport may not be eligible if air quality is not an issue in that region.
- Grants are competitive, and airport could invest time pursuing an award without winning.

### Zero Emissions Vehicle and Infrastructure Program

FAA's zero emissions vehicle (ZEV) and Infrastructure Program offers funding for up to 50% of the cost for airport zero emissions vehicles and for equipment to recharge or refuel the cars, trucks, and buses (FAA 2017c). Vehicles could be electric or hydrogen powered. The grant's purpose is to cover the price premium an alternative vehicle may carry and to address upfront investments necessary to power the vehicle. Airports in air quality nonattainment areas are given first priority for grant consideration.

**Pros**

- Grants can cover vehicles and infrastructure under same application.

**Cons**

- Awards are made on a competitive basis with the possibility of an airport submitting an unsuccessful proposal.

### Airport Improvement Program and Passenger Facility Charges

Airports could dedicate airport improvement program (AIP) and passenger facility charges funding to purchase either renewable energy or energy efficiency upgrades as part of a broader capital project. Potential opportunities to combine emissions reduction with an existing capital investment include terminal expansion, parking garage retrofit, new facilities, or other landside building projects.

**Pros**

- These upgrades simplify grant application if emissions reduction components are contained within larger capital investment.
- Upgrades make efficiency an integrated component of a building project.

**Cons**

- Upgrades may reduce the amount of funding available for essential airport services.

## Energy Efficiency Grants

In 2012, Section 512 of the FAA Modernization and Reform Act (Public Law 112-95) included a program for projects that increase the energy efficiency from airport power sources. This legislation made these projects eligible for AIP grant funding, without a dedicated special set-aside. Airport participation has been limited to date. Nevertheless, at least two grants in 2018 were valued at over $1 million each (FAA 2019b). This program includes power purchase agreement (PPA) requirements for solar installations within the airport fence line as well as requirements for obtaining and selling renewable energy credits (RECs).

**Pros**

- Program provides authority for airport to pursue projects with the primary purpose of saving energy.

**Cons**

- Funding proposal competes with AIP funding of all forms, and projects that support aeronautical uses of revenue will be prioritized.

## State Grants and Utility Rebates

Airports can pursue incentives that include tax credits, grants, rebates, and bonds—options designed to encourage energy-efficient actions. Each state has adopted its own selection of programs for efficiency. On-site renewable energy generation is also incentivized in many states. States may have emerging grant options offered out of a clean energy office (such as those for microgrids). Multiple utilities also participate in public utility commissions and offer additional rebates for efficiency and for conversion to lower-emissions equipment or vehicles.

Given the vast breadth of options, it is recommended that airports search a reliable database to see which choices prove most appropriate. Databases are the American Council for an Energy-Efficient Economy (ACEEE) State Programs or the DSIRE Database of State Incentives for Renewables and Energy Efficiency (American Council for an Energy-Efficient Economy 2018; North Carolina Clean Energy Technology Center 2019), among others.

**Pros**

- State and utility incentives deliver funding from an external source at the airport.
- Many options are guaranteed and do not require a competitive bid.
- Programs are often at a mature stage of development, and applications for subsidies or other types of incentives are streamlined.

**Cons**

- The size of each incentive may be modest.

## Aircraft Fuel Taxes

FAA mandates that taxes from aircraft fuel must be dedicated to airport capital projects (FAA 2017d). Each state decides how this funding will be allocated. Airports should speak with their FAA regional district office to determine which state agency currently determines

how this funding is distributed. For most states, the group overseeing this funding source falls within the transportation group (e.g., the Aeronautics Division or the Department of Aviation), which supports small commercial and general aviation airports.

**Pros**

- Taxes leverage an external source of funding.
- Source will likely grow as air travel demand increases and alternatives to conventional fossil fuel are limited.

**Cons**

- Smaller airports already receive these funds and use them for essential aeronautical purposes (e.g., runway expansion).

### Greenhouse Gas Markets

There are multiple GHG emissions markets in the United States. California passed the Global Warming Solutions Act (AB 32) in 2003, which requires a cap on the total emissions and requires payment for firms that produce $CO_2$ above a specified threshold. These fees are then redirected into the GHG Reduction Fund to pay for projects that reduce emissions via California Climate Investments. The payments cover allowances, which are created by entities that either reduce their own emissions below the required maximum level or generate direct emissions savings. In the Northeast, the Regional Greenhouse Gas Initiative (RGGI) operates in a similar way, and the following states participate: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. Airports could pursue projects that may be eligible to function as tradable allowances.

**Pros**

- External source of funding dedicated to emissions savings.
- Payment grows with the size of the emissions eliminated.

**Cons**

- Allowances are generated by emissions projects offering the lowest marginal cost for reduction.
- Airport-based projects may not be competitive with other sites that can be dedicated to renewable energy or other reduction projects.

## 5.2 Airport-Based Funding

Mechanisms in this section rely on existing or new airport revenue and are subject to FAA grant regulations.

### Capital and Operational Budgets

Airports may choose to fund emissions savings from their existing capital and operational budgets. For example, with a capital project, an airport may decide to upgrade the electrical

service for a building so that electric vehicle charging stations can be installed. Both the costs of increased voltage and the stations themselves could be funded this way. Similarly, an airport may choose to replace a single, existing motor with a more efficient product in its heating, ventilation, and air conditioning system as part of its operating budgets. The difference in these two examples arises from the size of funding required, and that may be the single contributing factor between having to rely on the longer planning horizon for the electric vehicle project using capital funds.

**Pros**

- Airport uses conventional revenue sources, minimizing the need for stakeholder education and coordination.
- Smaller projects can be funded at the end of the budget year if operational dollars are allocated but unspent.

**Cons**

- Other priorities require airport revenue and may limit funding available for emissions reductions.

## Green Revolving Funds

Green revolving funds (GRFs) are financial tools that use money in an account to finance a project that simultaneously improves efficiency and offers an environmental benefit, such as emissions reductions. Cost savings from the improved efficiency are added back to the original account and can be used toward additional projects (Indvik et al. 2013). Requiring only an initial investment, a GRF can then pay for myriad subsequent projects that improve efficiency and reduce emissions. Additionally, a portion of the savings realized through the GRF could be set aside and used to repay the funder contributing the initial principle (Better Buildings n.d.).

GRFs have been successfully implemented at higher education institutions and in municipalities. For over a decade, universities have captured operational savings from projects to create an alternative funding stream for new projects. A GRF provides a system to prioritize projects based on the return on investment, track utility savings once they have been completed, and direct cost reductions to a centralized fund. GRFs offer potential for funding emissions savings actions that also reduce operational costs.

Airports have just begun to adopt GRFs. Hartsfield-Jackson (ATL) has a sustainability resource fund, capitalized through a fee on large capital projects. Atlanta negotiated this arrangement with airlines to create a more flexible method to fund efficiency projects. The fund's size is over $1M; at present, the fund does not have a revolving feature with savings returning. The Department of Aviation, Virginia, created a state-wide revolving fund to cover capital projects at its smaller airports and to offer an alternative grant mechanism that can cover investments that will generate revenue. The Department of Aviation charges a modest interest rate to airports for covering its own operational costs and for keeping ahead of inflation impacts. By creating a state-wide centralized fund, Virginia can minimize administrative costs and provide services that a smaller airport many not be able to manage independently.

Airports should consider starting their own individual funds if they have more than 1 million passengers per year or annual utility expenditures (electricity, fuel and water) above $1 million. If the operations or utility spending are lower than these thresholds, an airport would be better served by participating in a fund run from the state level. *ACRP Research Report 205: Revolving*

*Funds for Sustainability Projects at Airports* provides extensive guidance on how to adopt a GRF at an airport (Klauber et al. 2019).

**Pros**

- Once operational, GRFs can generate a significant alternative source of funding.
- GRFs offer a structural framework to collaborate with airlines and tenants to maximize efficiency.

**Cons**

- Implementation requires extensive stakeholder education and coordination.
- Airline agreements may have to be modified to allow operational savings to be retained.

## Power Management Opportunities

Back-up power and microgrids offer the ability to generate revenue and reduce utility costs by managing airport energy consumption (NREL 2019). By using on-site stored energy (from batteries or, potentially, thermal storage), an airport can reduce the electricity it takes from the grid. Grid operators offer programs for facilities that can shift energy loads when risk occurs that electricity generation may not be sufficient. These programs are called "demand response" (DOE 2019a). In return for reducing their draw from the grid, airports receive payment from grid operators. If airports rely on diesel generators, there may not be a net reduction in emissions due to the on-site fuel burn.

Airports can also use on-site power generation and storage to reduce their total consumption and avoid charges for peak demand. Shifting time-of-use or reducing consumption at the highest levels will reduce utility costs. In the future, airports with functional microgrids may be able to offer "transactive" services, such as island power when the larger electrical grid experiences outages (Gridwise Architecture Council 2018).

**Pros**

- Generates operational savings without investing in additional infrastructure.
- Once in place, management and labor requirements may be minimal.

**Cons**

- Demand response participation may be distracting for building engineers when routine airport priorities must be addressed first.
- Microgrids are complex and implementation requires significant resources.
- Emissions tradeoffs exist if airports rely on fossil fuels for back-up power generation.

## Tax Exempt Financing

Airports with functional status as a utility can leverage tax-exempt funding from bonds (Barrett 2015). The airport can purchase an electricity volume over a long-term period. The duration can extend 20 years or more, and that funding can be used to capitalize a renewable energy project at an airport. The airport with utility authority can recoup costs by selling the

electricity to its tenants and back to itself, producing favorable returns over time. An airport must consult with legal and finance experts regarding technical details for this contractual structure before issuing any bonds. Airports without authority to act as a utility, depending on the future of the federal tax credit for solar installations, will need to work with a third party eligible to receive the benefit.

**Pros**

- Airports with the authority to act as a utility could receive the benefit of favorable financing conditions indirectly without utilizing their own capital.
- Indirect subsidies allow generated electricity to be sold to airports at prices below market rates from grid-sourced power.

**Cons**

- Most airports do not have the authority to act as a utility entity.
- For airports without utility authority, a third party must own the renewable energy asset (as these airports would not be eligible for the tax credit).

## 5.3 Third-Party Funding

Funding mechanisms presented in this section are obtained by a third party and do not require airport capital. Given the variations on ownership and operational models, airports may experience differing comfort ranges with the options.

### Power Purchase Agreements

Power purchase agreements (PPAs) equip an airport to secure renewable energy, either on site or at a remote location (DOE 2019b). Under a PPA, an airport contracts with a service provider to install photovoltaic panels on the roof or mounted on the ground of the property. The service provider obtains financing from a third party and maintains the equipment for the duration of the contract, which typically lasts from 20 to 25 years. Airports gain the benefit of adding solar capacity to the grid and being able to generate electricity at the airport. Contractors receive an airport's payment for power supplied from the solar installation and have the security provided by the long-term contract. Both parties benefit from the associated guaranteed price and budget certainty, and the airport does not need to expend any upfront capital.

Under a virtual PPA, an airport executes a contract for renewable power produced on non-contiguous land away from the property (EPA 2016d). With virtual PPAs, airports can buy renewable electricity produced from wind as well as solar. Typically, power prices are lower with virtual PPAs that can secure supplies from utility-scale renewable projects with better economics than smaller on-site installations.

In conventional PPAs and virtual PPAs, renewable energy credits (RECs) are produced along with electricity (EPA 2018). RECs are commodities that allow utilities to comply with state Renewable Portfolio Standards through procurement, rather than having to develop and operate renewable energy production. RECs are usually retained by the project developer with purchase agreements. So, airports may have to pay additional funding to retain their RECs or to secure them from a secondary source, if they are required for green building or Airport Carbon Accreditation certifications.

**Pros**

- Airports do not have to use their own capital.
- Development and maintenance are performed by the contractor.

**Cons**

- Airports will pay for electricity that they would have obtained at no cost if they had implemented the project.
- RECs are owned by the contracted project developer.

## Energy Savings Contracts

An energy savings contract (or performance contract) is a method allowing airports to leverage external engineering upgrades, combined with third-party financing. Energy savings contracts are a low upfront cost strategy that reduces overall energy consumption at specific buildings across an airport. In general, an energy service company (ESCO) implements the efficiency upgrades and is selected through competitive procurement. ESCOs then create a package of building-specific upgrades with an extended payback (typically around 10 years) and secure a loan from a bank to cover their labor and equipment costs. Efficiency gains can range between 20% and 35%, and individual projects include HVAC system replacement, retro-commissioning, and lighting improvements.

The most common form of energy savings contract is an energy savings performance contract (ESPC) (DOE 2019c). An airport pays an ESCO over the term of the ESPC through a portion of energy efficiency savings. For example, after an audit, the ESCO might determine that it can reduce utility costs by at least 25% per year. The ESCO would collect a portion of the savings. Given the requirement to achieve a minimum threshold, ESCOs can usually deliver savings beyond their contracted amount. Any savings above the minimum guarantee accrue directly to the airport at no additional cost.

Four main steps are required for entering into an energy services contract, as shown in Figure 18. These are to understand the different contracting mechanisms; choose the best approach for the airport; evaluate procurement methods and solicit a proposal from energy services contractors; and select the best proposal and enter into a contract.

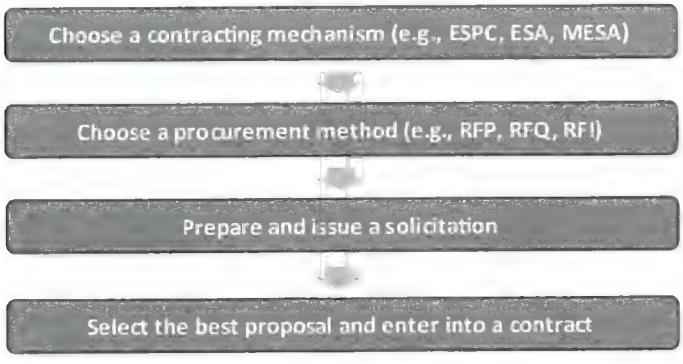


***Figure 18. Process for establishing an energy services contract.***

**Table 15. Characteristics of energy savings contracts (Kim et al. 2012).**

| | ESPC | ESA | Managed ESA |
|---|---|---|---|
| Ownership | Airport owns all improvements throughout the term. | Project developer owns improvements during the term. Airport may purchase them when the term ends. | Project developer owns improvements during the term. Airport may purchase them when the term ends. |
| Funding upfront costs | Airport uses debt or loan financing, if needed. | Project developer is responsible for arranging 100% of the capital. | Project developer is responsible for arranging 100% of the capital. |
| Market penetration in airport sector | High | Low | Low |
| Typical project size | Unlimited, but transaction cost may be too high for very small projects | $250,000 to $10 million | $250,000 to $10 million |
| Responsibility for utility bills | Airport or ESC | Airport | Managed ESA provider |
| Responsibility for operations and maintenance | ESC (usually; can be specified in contract) | Project developer/ESC | Project developer/ESC |
| Guarantee of energy savings at a certain level? | Yes | Usually; can be specified in contract | Usually; can be specified in contract |
| Contractor conducts baseline measurement of energy use and ongoing measurement and verification | Yes | Yes | Yes |
| Guaranteed maximum fixed price? | Yes | No, price is on a relative basis rather than fixed (i.e., price per unit of energy saved or per dollars in energy savings). | No, price is on a relative basis rather than fixed (i.e., price per unit of energy saved or per dollars in energy savings). |

Two of the other less common types of energy savings contracts are an energy services agreement (ESA) and a managed energy services agreement. Each contracting mechanism has different arrangements for how and when cash flows from energy savings are shared among an energy savings contract, a finance provider, and an airport. These contracting mechanisms are summarized in Table 15.

Energy savings contracts differ from the traditional design/bid/build model. The process and working framework in an energy savings contract is simpler from the airport facility's perspective. As shown in Figure 19, the ESCO and/or project developer manages all work (e.g., audit, design, construction, measurement and verification) and assumes project liability. This is indicated by the gray dotted line showing airport-only contracts with one entity—the ESCO. Within an ESPC, even if the ESCO does not provide direct financing, it often assists the airport facility with financing procurement (indicated by the dashed line in the figure). Within an ESA or managed ESA, the ESCO funds all investments. Therefore, energy savings contract projects tend to be turnkey, and the developer guarantees the savings that pay for the project, imposing relatively low risks on the airport.[4]

[4] Most state regulations on energy savings contracts require that the energy savings contract guarantee the saving level that the project will achieve.

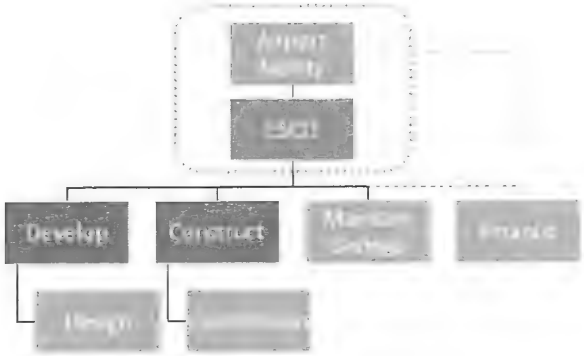


***Figure 19. Airport responsibility in an energy services contract.***

**Table 16. Airports that have energy savings contracts.**

| Airport | City | State | Year |
|---|---|---|---|
| Bangor Airport | Bangor | ME | 2009 |
| Honolulu International Airport | Honolulu | HI | 2017 |
| 11 airports | Various cities | HI | 2017 |
| Valley International Airport | Harlingen | TX | 2005 |
| City of Dallas—Love Field | Dallas | TX | 2008 |
| Austin Bergstrom International Airport | Austin | TX | 2009 |
| Hartsfield-Jackson Atlanta International Airport | Atlanta | GA | 2017 |
| Miami International Airport | Miami | FL | 2015 |

Table 16 shows a partial list of airports of various sizes that have entered into energy savings contracts to reduce their energy consumption and GHG emissions in recent years, for projects ranging from parking lot LED light retrofits to large-scale solar PV arrays (AMERESCO 2012; Georgia Association of Energy Engineers 2017; Hawaii DOT 2017).

More information on energy savings contracts is available in *ACRP Report 71* (Kim et al. 2012).

**Pros**

- Airport leverages third-party financing.
- Multiple projects can be implemented simultaneously as part of a broad ESPC.
- There is relatively low financial risk to the airport as energy savings are guaranteed by contract.
- A single entity manages all project components, thus reducing the airport's overhead compared to design/bid.

**Cons**

- ESPCs require significant airport staff time for coordination, contracting, and execution, including ensuring the baseline and assumptions for measuring future savings are acceptable. (Note: LaaS contracting is considerably streamlined).
- ESCOs ultimately determine which projects they will include in the contract, not the airport.

**Pros**

- ESCOs will likely exceed a minimum performance target as they must be conservative with their estimates; those operational savings accrue directly to the airport.

**Cons**

- Long contracts (~10 years) reduce airport financing flexibility.

## Public-Private Partnerships

A public-private partnership, also known as a P3, is a contractual relationship between a public entity (an airport, in this context) and a private sector entity or entities (U.S. DOT Build America Bureau 2018). The contract allocates responsibility for service delivery, capital investment, and risk assumption. Any P3 should make it possible to improve the efficiency of transportation. The P3 usually indicates a structure by which services or investments, traditionally provided by an airport's sponsor, are provided by a private sector firm (Kaplan Kirsch and Rockwell 2017).

In the past, P3s have been viewed skeptically by the public. A number of early prominent efforts at P3s were characterized as transfers of publicly valuable assets to private firms. Several toll roads had private operators filing for bankruptcy and had to be taken back by a public agency. In the U.S. airport industry, early discussions focused on full airport privatizations modeled on similar transactions in other global regions (e.g., under the FAA's authorized Airport Privatization Pilot Program). Currently, P3 structures have started at terminal projects at JFK and LaGuardia, the Great Hall project at Denver, and the newly privatized terminal at Paine Field in Everett, north of Seattle (Kaplan Kirsch and Rockwell 2017).

P3s offer a possibility to mobilize private sector funding for large retrofit projects, and this approach may be appropriate for airports lacking other resources to modernize selected facilities, thus dramatically reducing emissions.

Projects undertaken can range from building of physical infrastructure to operations. These partnerships can offer new approaches for taking on the project, different financing options, and different risk amounts and types than the government would face alone. P3s can be tremendously effective or tremendously costly, depending on a multitude of factors (Marques de Sá 2017). In exchange for certain rights and abilities to recoup costs over the project's life, private partners are often willing to supply upfront capital, which can be especially useful for expensive emissions reduction projects. P3s also can allow the private sector to take certain risks, which the government might not be able to do, even if it had the will (Baietti 2013).

**Pros**

- Significant funding can be generated more quickly by private entities.
- Airports can selectively partner on the most challenging assets if they find willing partners.

**Cons**

- Airports transfer the asset's ownership for the long term.
- Currently held assumptions of P3 structures may be negative.

### As a Service Model

Airports may be able to leverage third-party providers to support an airport function previously seen as an infrastructure cost. For specific performance areas (such as lighting), private firms will provide a service, shifting installation, maintenance, and replacement costs from the airport. Airports already have experience with contracted custodial work and may utilize this approach with companies that offer floor covering as an ongoing service (instead of just selling carpet material).

Related to emissions, some companies offer Lighting as a Service (LaaS). Under this model, airports can contract a complete performance area and specify the quantity (lumens) and quality of illumination they require. A service provider is then responsible for maintaining and replacing the lighting. Long life and energy-efficient LED options are likely choices for contractors. Energy performance can be one of the specifications of the contracted LaaS.

**Pros**

- Improved emissions savings measure can be implemented on a more frequent basis.
- Airport does not have to generate the capital for upgrades.
- Airport does not have to maintain the asset.

**Cons**

- Airport does not have direct control of the service.
- Services are limited to areas where a vendor can make a profit.

### Green Leases

Airports can include sustainability performance incentives in their tenant rental agreements. If sub-metering is possible, airports can measure existing energy consumption from each lease and establish baseline usage values for electricity, fuel, and water. Using these data, airports can encourage concessionaires and airlines by granting them a favorable split if they install more-efficient equipment and find ways to reduce consumption through operational modifications. Tenants invest their own funding to make these changes. Airports can promote participation and potentially competition by recognizing participation and promoting high performance by posting signage or digital display content visible to passengers. ACRP has provided specific guidance on contract language and best practices in *ACRP Synthesis 42* (Hazeman 2017).

**Pros**

- Tenants are responsible for new equipment or retrofit actions.
- Tenants are incentivized to change their behavior and conserve energy.

**Cons**

- Airports may have to wait until contracts are renegotiated to implement.

### Passenger Voluntary Contributions

Passengers can pay to "offset" their aircraft emissions. Many airlines have offered passengers an option to purchase carbon credits as part of an airline ticket transaction. Currently, it is

difficult to find these programs, and passengers unaware of them will not consider this action as they will not know to look for the option on the airline site. It is understandable that airlines prefer selling higher-margin services as part of the ticket transaction. It is far more profitable to sell extra leg room or expedited boarding privileges than for an airline to provide an option to buy carbon reduction provided by a third-party developer.

San Diego Airport launched The Good Traveler carbon reduction program in 2016 to directly engage passengers, so they can take voluntary action (see "The Good Traveler" in Chapter 4). Passengers can estimate their emissions on The Good Traveler website and neutralize them by paying a relatively modest fee in comparison to their flight's price. The Good Traveler purchases carbon credits on their behalf, verified by third-parties and connected to projects in the regions where the airports are located. In 2019, over 14 airports in the United States were members and post physical or digital signage in their terminals. In the future, The Good Traveler has plans to support "in-sector" carbon reduction that will support purchases of low-carbon, sustainable jet fuel or create a funding stream that can accelerate aircraft fuel efficiency (Good Traveler 2019).

**Pros**

- Passengers are empowered to participate in aviation emissions reduction.
- Airport does not have to make significant investment.

**Cons**

- Achieving higher participation levels requires effectively promoting the program, which could include substantial coordination with airport IT, communications, and tenants regarding signage and other educational content.

CHAPTER 6

# Monitoring and Outreach

Once the roadmap is completed and publicly released, the core decision-making team discussed in Chapter 2 needs to establish internal processes to ensure the roadmap can be maintained over time. Additionally, the core decision-making team should have been coordinating with the airport's public affairs office during the roadmap development to ensure an effective outreach program. These post-roadmap development items are the focus of Chapter 6 and are illustrated in Figure 20.

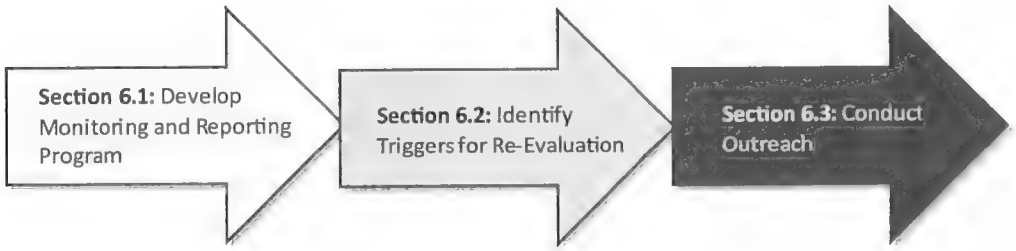


*Figure 20. Steps for monitoring and outreach.*

## 6.1 Develop Monitoring and Reporting Program

### Developing a Monitoring Program

#### *Frequency of Assessment*

The first step in developing an effective GHG emissions monitoring program is to choose a consistent assessment frequency. GRI recommends annual reporting, as this allows for consistent and timely assessments of progress towards meeting an established emissions goal and developing emissions trends. Once a reporting frequency has been chosen, that same frequency should be used throughout the goal period. Figure 21 depicts a flowchart of an emissions monitoring program.

#### *Greenhouse Gas Inventory and Calculating Emissions*

When monitoring and reporting emissions for a reporting year, a GHG inventory should be conducted. Reporting year emissions should be reported separately by gas (in metric tons) and by carbon dioxide equivalent ($CO_2e$) (in metric tons). Upon assessing reporting year emissions, the change in emissions since the start of the goal period should be calculated. Knowing the change in emissions can help airport staff understand the attainability of the emissions reduction goals for the target year as well as showcase how far the airport has advanced, helping ensure


***Figure 21. Airport emissions monitoring program flowchart.***

that the airport remains on the right track for attaining its established goals. The following formula provides the change in emissions for a reporting year:

$$\Delta \text{ emissions since start of goal period} = \text{reporting year emissions } (t\,CO_2e) - \text{baseline emissions } (t\,CO_2e)$$

After calculating the change in emissions since the start of the goal period, the next step is calculating additional emissions reductions that may be necessary to achieve the reporting year goal:

$$\text{reductions needed to achieve the goal } (t\,CO_2e) = \text{reporting year emissions } (t\,CO_2e) - \text{allowable emissions in target year } (t\,CO_2e)$$

With the necessary data calculated for emissions in the reporting year, the airport should assess *why* emissions have changed since the start of the goal period. This assessment should determine whether emissions changed as a result of new technologies and policies, growth or decline in business, seasonal weather variations, or some combination. Each reporting year, the airport should take stock of every potential GHG emissions driver, in addition to sources established in the GHG inventory, and should collect data on how each driver has changed over the goal period. With this information, the airport can estimate the fraction of the total emissions changes that can be attributed to each driver (e.g., how much change results from more efficient shuttle buses versus how much results from a change in the number of shuttle bus miles traveled).

After each reporting year, clear trends should emerge that show whether or not the airport heads in the right direction and remains on track to meet its target-year reduction goal. Establishing these trends allow airports to pivot, change, or stop strategies, depending on how well they are working.

## Effective Reporting

Having a concise and easy to understand mechanism for communicating progress on zero- or low-emissions planning is important for keeping internal and external stakeholders up to date and for holding the airport accountable. Many airports publish an annual sustainability report, which includes all efforts made on reducing emissions. Of these airports, some establish their own methods for organizing and structuring the reports. Recent trends in private sector reporting and disclosure have been adopted by the aviation industry, bringing consistency to airport annual reporting.

### *Global Reporting Initiative*

Airports are encouraged to familiarize themselves with the Airport Operators Sector Supplement developed by GRI, as GRI collaborates with industry stakeholders to develop the most widely adopted global standards for sustainability reporting. GRI's reporting framework is intended to provide a method for reporting on an organization's economic, environmental, and social performance. GRI Standard 305 requires disclosures on Scope 1, Scope 2, and Scope 3 GHG emissions, GHG emissions intensity, and reduction of GHG emissions, in addition to ozone-depleting substances and other pollutants (GRI 2019). These seven standard disclosures are summarized in Table 17.

Disclosure of GHG emissions reductions means publicly reporting on GHG emissions reduced as a direct result of reduction activities, as opposed to other drivers, the scopes in which reductions took place, and the methodologies and assumptions used. GRI guidance indicates that offsets can be included as part of reduction efforts, but these must be reported separately. Any additional details that airports provide regarding progress toward emissions goals (such as specific offsets purchased) increase transparency and provide stakeholders with a thorough record of airport emissions reduction activities. Airports such as San Diego International Airport, Toronto Pearson International Airport, and Amsterdam Airport Schiphol all prepare their annual reports in accordance with GRI Standards.

In addition to preparing its annual reports in accordance with GRI Standards, Toronto Pearson International Airport has an active stakeholder engagement process. The airport undertakes a comprehensive materiality assessment every 5 years to ensure it is tracking and reporting on the elements most important to its stakeholders and publishes the results on its website. The airport gathers information from stakeholders more frequently as well as through industry committees, passenger surveys, employee forums, public meetings, customer and passenger feedback kiosks, a web portal, and social media channels as described in the airport's Sustainability Management Approach and GRI Index.

**Table 17. Global Reporting Initiative 305 emissions disclosures.**

| Standard Disclosure | Topic |
|---|---|
| 305-1 | Direct (Scope 1) GHG emissions |
| 305-2 | Energy indirect (Scope 2) GHG emissions |
| 305-3 | Other indirect (Scope 3) GHG emissions |
| 305-4 | GHG emissions intensity |
| 305-5 | Reduction of GHG emissions |
| 305-6 | Emissions of ozone-depleting substances (ODS) |
| 305-7 | Nitrogen oxides ($NO_X$), sulfur oxides ($SO_X$), and other significant air emissions |

### *Integrated Reporting*

Integrated reporting is a concept developed by a coalition of corporate reporting entities to advance corporate reporting into areas focusing on value creation. According to the International Integrated Reporting Council (IIRC), integrated reporting is "a process founded on integrated thinking that results in a periodic integrated report by an organization about value creation over time and related communications regarding aspects of value creation." The integrated report resulting from this process "is a concise communication about how an organization's strategy, governance, performance and prospects, in the context of its external environment, lead to the creation of value in the short, medium and long term (IIRC)." Amsterdam Airport Schiphol and Munich International Airport are examples of airports that both practice integrated reporting and follow GRI Standards. Zero- or low-emissions planning proves well-suited for inclusion within an airport's integrated report as it touches on several opportunities the airport has to create value.

Producing a report is just one way airports can showcase the progress and success of their emissions reduction efforts. Increasing public awareness of zero- or low-emissions planning at the airport can enhance the airport's reputation, build goodwill, and potentially encourage additional stakeholders to become involved. Tactics for increasing awareness of zero- or low-emissions planning and related efforts include the following:

- Integrating updates on zero- or low-emissions planning efforts across all communications channels (such as newsletters, email, and social media);
- Participating in civic groups and business organizations, including business chambers and economic development/tourism offices;
- Highlighting emissions planning and reduction efforts through speaking engagements and airport tours;
- Highlighting emissions planning and reduction efforts via prominently displayed airport signage and posters in common areas; and
- Hosting open houses and community meetings that highlight emissions reduction efforts.

**Munich International Airport Pursues "Integrated Thinking" Approach**

Munich International Airport has been publishing integrated annual reports since 2011, providing updates on economic, environmental, and social aspects together. Guided by the framework developed by the International Integrated Reporting Council, Munich Airport conveys its activities that create short-, medium-, and long-term financial and non-financial value (Flughafen München GmbH, 2019).

## 6.2 Identify Triggers for Re-Evaluation

A number of factors, internal and external, could result in an airport revising its GHG emissions reduction targets. External factors include new advances in technology (making more ambitious emissions reduction targets feasible over a shorter period of time). Regulation changes could require airports to adopt certain practices or technologies. Unexpected challenges, such as natural or man-made disasters, or anything that fundamentally changes an airport's business model, may alter the cost-benefit calculus for emissions reduction. Internal factors that could cause revisions include the airport substantially missing a reporting year goal and no longer remaining on track to achieve allowable emissions by the target year.

Continually accounting for advances in energy, building, and transportation technology, both on-site and off-site, as well as risks from disruptions or changing business trends, can help airports take full advantage of opportunities available to reduce emissions—and to revise targets, when appropriate.

### Technology and Policy Changes

Though technology changes are usually adopted voluntarily, it may be useful for airports to set specific timelines on which to assess the state of emerging technologies and consider the

readiness, benefits, and costs of adopting them. A period from every 3 to 5 years may be appropriate, given the innovation pace for building and energy efficiency products.

Policy changes can be anticipated or unanticipated. Changing political parties in local, state, and federal government, along with shifting public attitudes, can affect the tools airports can use to meet emissions reduction targets. Airports can anticipate policy changes by maintaining a dialogue with policy-makers regarding emissions reduction targets and emissions reduction strategies. Making a business case for continual emissions reduction (see Section 1.3) can aid in this effort.

### Disruptions and Business Cycles

Unexpected shocks, such as natural disasters or business cycle shifts, could force airports to slow their expected emissions reduction targets (e.g., as they recover) or encourage them to accelerate investment (e.g., to become more resilient to the next disruption or downturn). Each airport will find itself in a different context. In the event of a disaster, an airport's stakeholders may push for any renovation or rebuilding to take place in a manner which enables more ambitious reduction targets. However, a disaster that results in a large amount of damage may constrain resources to the extent that airports must forgo investments in emissions reduction technologies and practices for some period of time, as to focus resources on more immediate concerns.

In an economy on the upswing, airline ridership will continually increase, fueling revenue for airports to invest more into emissions reduction strategies than initially anticipated. In a recession, declining ridership and revenue may force airports to forgo expected emissions reduction strategies that require significant new capital. At the same time, decreasing utility energy can help enhance airports' bottom lines in downturns.

Table 18 describes potential changes that could trigger the need for re-evaluation of airport emissions reduction targets, broken down by emissions scope.

## 6.3 Conduct Outreach

Conducting outreach entails engaging with external stakeholders, such as community members, vendors, and tenants. People living near a site and businesses that operate within and surrounding airports stand to benefit most from changes such as improved air quality. So outreach to these affected stakeholders remains crucial. Chapter 2 provides guidance on identifying an airport's external stakeholders.

Conducting outreach for emissions reporting and progress towards an emissions reduction goal provide results similar to initial outreach, performed for establishing goals and a roadmap. Rather than collaborating with stakeholders to create the goals and a roadmap to reach them, the airport has a chance to inform stakeholders on the progress they have made, the challenges they have encountered, and the areas that still have room for improvement. This external communication should include input from the airport's marketing and communications teams.

An airport's emissions reduction progress outreach toolbox provides multiple tools:

- Emissions reduction program fact sheet,
- Customer emissions reduction program survey,
- Stakeholder meetings,
- Emissions reduction progress report open houses,
- Social media, and
- Internal marketing (e.g., airport advertising space and announcements).

**Table 18. Potential triggers for re-evaluation of airport emissions reduction targets.**

| | Scope 1 | Scope 2 | Scope 3 |
|---|---|---|---|
| Technology | New classes of HVAC equipment become available | New renewable energy generation technology | Mass adoption of electric vehicles (used by employees and passengers) |
| | Addition of on-site renewable energy technology (e.g., solar panels) | New renewable energy storage technology | New sustainable aviation fuel technology becomes available |
| | Alteration/expansion of airport facilities (e.g., renovation of terminal increases insulation) | | New transportation options to airport (e.g., new rapid transit system, fuel efficient buses, new routes) |
| Policy | Regulation requires airports to adopt specific on-site technology or to limit on-site emissions | Regulation requires airports to purchase specific amount of energy produced by renewables | Policy incentivizes airport employee commuting or passenger arrival via new method (e.g., shared vehicles replace single-occupancy cars) |
| | Regulation requires airports to adopt specific emissions target | | |
| Disaster | Natural or man-made disaster forces airport to defer investment in emissions reduction strategies to focus on immediate concerns | | |
| Business Cycle | Revenue reductions force deferment of capital-intensive, on-site, renewable energy generation technology or electrification (e.g., solar panels) | Price of fossil fuels dramatically falls, reducing benefit-cost of purchasing green energy | Budget cuts reduce public funding for sustainable transportation to airport |
| | | Price of renewable energy dramatically falls, incentivizing greater purchase of green energy | Price of gasoline falls, encouraging employees and passengers to arrive to airport by single-occupancy vehicle |
| Internal | Internal emissions reduction target is missed within a given year | | |
| | Internal emissions reduction target is exceeded within a given year | | |

If an airport has the resources to support a dedicated marketing or communications team, outreach should fall within their skill set. Smaller airports may have to rely on other team members for outreach duties. For resources on conducting surveys, hosting meetings, and other communication tools, see Chapter 2.

Diverse engagement avenues are key to successful outreach. Whether social media, an open house, or a survey, some key questions should be asked of participants to inform future communications on emissions reduction progress—and potentially the emissions reduction strategies themselves:

- Have you heard about the airport's GHG reduction program?
- Why is it important to you that the airport reaches its GHG reduction goals?
- What do you think the airport is doing well in meeting its GHG reduction goals?
- What do you think the airport could do better in meeting its GHG reduction goals?
- How could progress be better conveyed?

Questions should be tailored for before and after the release of public progress to gauge public interest and to receive comprehensive feedback. Community members can often offer a unique perspective, and they may think of something overlooked by the airport team. Ensuring a cyclical process of receiving feedback, incorporating feedback, and asking for more feedback in each reporting year will lead to a stronger emissions reduction plan. This also poses an ideal opportunity to showcase how customers' and tenants' dollars are spent to further sustainability efforts.

### Metropolitan Airports Commission Airport Sustainability Outreach and Engagement

The Metropolitan Airports Commission (MAC) owns and operates Minneapolis–St. Paul International Airport (MSP) and six reliever airports. In 2013, MAC developed a sustainability management plan, which was updated in 2019. As part of the refresh effort, MAC conducted outreach across the organization and developed four sustainability goals to achieve by 2030, including a goal to reduce GHG emissions by 80% by 2030 from the 2014/2015 baseline. The other three key goals were reducing water use per passenger by 15%; reducing, reusing, or recycling 75% of solid waste; and involving MAC employees on implementing sustainability initiatives and achieving an engagement score of 85. MAC employees responded to surveys that sustainability matters to the organization and is the right thing to do. The engagement score measures how aware employees are of MAC sustainability efforts, how knowledgeable they are of how to contribute, and, more critically, what areas employees feel are most important for MAC to focus its efforts. MAC provides information on its progress to date on each of the goals and actions it is taking to meet the goals through a regularly updated web dashboard.

### Port Authority of New York and New Jersey Climate Educational Tool

The Port Authority of New York and New Jersey (Port Authority) has numerous sustainability goals and initiatives across its portfolio of assets, including ACA participation by all five of its airports (JFK, LaGuardia, Teterboro, Newark Liberty, and Stewart). In 2020, the Port Authority launched an interactive educational resource for local residents, parents, educators and students titled "Fighting Climate Change" for Earth Day. The resource provides information on the carbon cycle, GHGs, the human impact on the environment, as well as the contribution of the transportation sector, including Port Authority operations, to climate change. The resource also outlines the actions that the Port Authority is taking to combat climate change, such as their commitment to reduce GHG emissions by 35% by 2025 and by 80% by 2050.

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# Acronyms

| | |
|---|---|
| **AAHK** | Airport Authority Hong Kong |
| **ACA** | Airport Carbon Accreditation |
| **ACERT** | Airport Carbon and Emissions Reporting Tool |
| **ACI** | Airports Council International |
| **AIP** | Airport Improvement Program |
| **APU** | auxiliary power unit |
| **ASU** | aircraft start units |
| **ATL** | Hartsfield-Jackson Atlanta International Airport |
| **AUS** | Austin-Bergstrom International Airport |
| **CAA** | Clean Air Act |
| **CAAFI** | Commercial Aviation Alternative Fuels Initiative |
| **CAEP** | Committee on Aviation Environmental Protection |
| **CARB** | California Air Resources Board |
| **CCHP** | combined cooling, heat, and power |
| **CDA** | Chicago Department of Aviation |
| **CDM** | Clean Development Mechanism |
| **CDP** | Carbon Disclosure Project |
| **CER** | Certified Emissions Reduction |
| **CHP** | combined heat and power |
| **CLEEN** | Continuous Lower Energy, Emissions, and Noise |
| **COP** | Conference of Parties |
| **CNCA** | Carbon Neutral Cities Alliance |
| **CNG** | compressed natural gas |
| **CORE** | Carbon Offset Research and Education |
| **CORSIA** | Carbon Offsetting & Reduction Scheme for International Aviation |
| **DFW** | Dallas-Fort Worth International Airport |
| **eGSE** | electric ground support equipment |
| **EPA** | U.S. Environmental Protection Agency |
| **ERU** | emissions reduction unit |
| **ESCO** | energy service company |
| **EUA** | European Union Allowance |
| **GAV** | ground access vehicle |
| **GHG** | greenhouse gas |
| **GHGP** | Greenhouse Gas Protocol |
| **GPU** | ground power units |
| **GRF** | green revolving fund |
| **GRI** | Global Reporting Initiative |
| **GSE** | ground support equipment |

| | |
|---|---|
| **GWP** | global warming potential |
| **HEFA** | hydroprocessed esters and fatty acids |
| **HFCs** | hydrofluorocarbons |
| **Hz** | hertz |
| **IATA** | International Air Transport Association |
| **ICAO** | International Civil Aviation Organization |
| **ICCT** | International Council on Clean Transportation |
| **IIRC** | Integrated Reporting Council |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **JFK** | John F. Kennedy International Airport |
| **KPI** | key performance indicators |
| **LaaS** | Lighting as a Service |
| **LAWA** | Los Angeles World Airports |
| **LAX** | Los Angeles International Airport |
| **LDC** | least developed countries |
| **LEED** | Leadership in Energy and Environmental Design |
| **LLDC** | landlocked developing countries |
| **LTO** | landing and takeoff cycle |
| **MaaS** | Mobility as a Service |
| **MassDOT** | Massachusetts Department of Transportation |
| **MSP** | Minneapolis-St. Paul International Airport |
| **NAAQS** | National Ambient Air Quality Standards |
| **NREL** | National Renewable Energy Laboratory |
| **OMP** | O'Hare Modernization Program |
| **P3** | public-private partnership |
| **PCA** | pre-conditioned air |
| **PFCs** | perfluorocarbons |
| **PHL** | Philadelphia International Airport |
| **PM** | particulate matter |
| **PPA** | power purchase agreement |
| **RaaS** | Resilience as a Service |
| **RACI** | responsible, accountable, consulted, and informed |
| **RAM** | Responsibility Assignment Matrix |
| **REC** | Renewable Energy Credit |
| **RGGI** | Regional Greenhouse Gas Initiative |
| **RMI** | Rocky Mountain Institute |
| **RPS** | renewable portfolio standard |
| **RTK** | revenue ton-kilometer |
| **SAF** | sustainable aviation fuel |
| **SAGA** | Sustainable Aviation Guidance Alliance |
| **SAN** | San Diego International Airport |
| **SBT** | science-based targets |
| **SBTi** | Science-Based Target Initiative |
| **SDG** | Sustainable Development Goals |
| **SFO** | San Francisco International Airport |
| **SIDS** | small island developing states |
| **SWOT** | strengths, weaknesses, opportunities, and threats |
| **TCR** | The Climate Registry |
| **TNC** | transportation network company |
| **ULSD** | ultra-low sulfur diesel |
| **VALE** | Voluntary Airport Lower Emissions |

| | |
|---|---|
| **VER** | Verified Emissions Reduction |
| **WBCSD** | World Business Council for Sustainable Development |
| **WRI** | World Resources Institute |
| **WWF** | World-Wildlife Fund for Nature |
| **ZEB** | zero emission bus |

APPENDIX A

# Glossary of Terms

**100% renewable.** A condition in which renewable resources (such as wind, solar, geothermal, hydro power, and biomass) supply all airport electricity.

**Airport Carbon and Emissions Reporting Tool (ACERT).** A method used by an airport operator to calculate their airport's GHG emissions by source.

**ACRP.** An industry-driven research program of the Transportation Research Board that examines problems faced by airport operators and develops near-term, practical solutions.

**Aviation Environmental Design Tool.** Tool that models dynamic aircraft performance in space and time, demonstrating interdependencies between aircraft-related fuel burn, emissions, and noise.

**Carbon neutral.** A condition in which airport-controlled $CO_2$ sources and sinks are zero.

**Carbon negative.** A condition in which airport-controlled $CO_2$ sources and sinks are negative.

**Climate neutral.** A condition in which airport-controlled emissions do not contribute to climate change. (Though similar to carbon neutral, this condition implies all GHGs are included).

**Climate positive.** A condition in which an airport goes beyond achieving net-zero emissions to removing additional emissions from the atmosphere.

**Deep decarbonization.** A condition in which airport-controlled emissions are dramatically lowered. Typically, this refers to an 80% reduction in GHGs relative to 1990 levels or 2005 levels.

**Intergovernmental Panel on Climate Change (IPCC).** Intergovernmental body of the United Nations, tasked with researching the natural, political, and economic impacts and risks of climate change, and with developing feasible response options.

**Low emission.** A condition in which airport-controlled emissions are low but positive. No numeric threshold has been defined for meeting this condition.

**Net-carbon negative.** This condition is the same as climate positive.

**Net zero.** A condition in which airport-controlled emissions are zero with use of offsets. This condition is similar to carbon neutral, but it includes all GHGs.

**Roadmap.** A methodical plan or strategy designed to achieve a particular goal.

**Zero carbon.** This condition is the same as carbon neutral.

**Zero carbon footprint.** This condition is the same as carbon neutral.

**Zero carbon growth.** A condition in which airport-controlled $CO_2$ emissions do not grow larger each year.

**Zero emissions.** A condition in which airport-controlled emissions are zero without the use of offsets. This condition can only be met when all end uses are electrified or use zero or negative emissions synthetic fuels.

APPENDIX B

# Frequently Asked Questions About Emissions Planning

**What are Greenhouse Gas Emissions?**

Carbon dioxide ($CO_2$) makes up the majority of GHG emissions with much lesser contributions from nitrous oxide ($N_2O$), methane ($CH_4$) and other compounds that contribute to global warming. For example, fossil fuels release $CO_2$ when used to generate electricity, in furnaces, and to power vehicles.

**Why Reduce Airport-Related GHG Emissions?**

Environmental, social, and financial reasons exist to reduce GHG emissions at airports. States and localities around the country have introduced goals to reduce GHGs and lessen their contributions to global warming impacts, and airport GHG reduction initiatives can play an important role in achieving these goals. Since GHG emissions are directly related to energy consumption, reducing or eliminating GHGs can lower energy bills and airport operating costs. GHG reduction measures at airports can produce also result in producing an additional added benefit by reducing their criteria pollution emissions.

**What are the GHG Emission Sources at Airports?**

Airport-controlled carbon emissions sources result from the following: use of gasoline and diesel fuel in vehicles; fossil fuel for heating; electricity for lighting and heating, ventilation, and cooling (HVAC); and other sources.

**What is the First Step in Reducing GHG Emissions?**

Estimating the amount of GHGs from different airport sources is the first step. This is necessary to develop a plan for achieving reductions. There are several easy-to-use tools such as Airport Carbon and Emissions Reporting Tool (ACERT) to estimate airport related GHGs.

**How Can Airport-Related $CO_2$ Be Reduced?**

Energy saving measures, such as switching to light-emitting diode (LED) lights and improving insulation, are examples of low-cost approaches to reduce GHG emissions. Purchasing renewable energy credits or installing renewable energy technologies on-site at the airport are other examples.

**How Can These Initiatives Be Financed?**

There are state and federal incentives to assist with energy savings measures. In addition, tax exempt leases, renewable energy cooperatives, power purchase agreements, and other mechanisms provide airports with low risk and low cost approaches to reduce GHG emissions. Grant programs, such as the Voluntary Airport Low Emissions (VALE) Program, can be used in some instances.

**Why Aren't Tenant Emissions Included?**

Most airports have not included GHG emissions associated with tenant activities—such as aircraft, shops, food service, or passenger vehicle trips—in their inventories. A primary reason for this is that airports do not control the activities of these businesses.

**Which Emissions are under the Airport's Control?**

Scope 1 and Scope 2 emissions are considered airport controlled. This primarily includes emissions from airport-owned and operated vehicles (e.g., security, maintenance) and on-site electricity and steam generation. According to the IPCC, aviation is responsible for approximately 2% of man-made $CO_2$ emissions, but this value does not include airport Scope 1 and Scope 2 emissions.

**Does It Make Sense to Replace Aircraft APU Energy with Electricity from a Coal Fired Power Station?**

Installing Fixed Electrical Ground Power (FEGP) and Pre-Conditioned Air (PCA) will reduce auxiliary power unit (APU) usage and thus emissions from aircraft at an airport. However, it will also increase either the airport's Scope 3 emissions from electricity sold to tenants or Scope 1 emissions if the airport has its own power. A large power station with coal generation will generate electricity more efficiently and with lower GHG emissions than an aircraft APU.

**Which Scope is Electricity Provided by an Airport to Tenants?**

If an airport operator uses electricity meters to measure power usage and then charges airlines and other tenants for their usage, the associated emissions should be Scope 2 or Scope 3. If the airport operator initially purchased the electricity from an electricity provider, the associated emissions should be Scope 3 and Scope 3A emissions, as the airport operator may be able to work with tenants to reduce electricity use. If, however, the airport operator generates the electricity from its own on-site station, these will be Scope 1 emissions.

**Which Scope Includes Leased Buildings, Equipment, and Vehicles?**

The boundaries of leased assets (such as building space, equipment, or vehicles) are determined by the selected organizational boundary and type of lease. Several factors determine how the accounting is performed, including the fraction of the year in which the asset is leased. The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard provides additional information on how to handle leased assets (WBCSD and WRI 2015).

**What are the Best Calculators for Estimating Emissions at an Airport?**

There are several easy-to-use GHG emissions inventory tools. One example is Airport Council International's Airport Carbon and Emissions Reporting Tool (ACERT) (ACI 2019). Other examples are included in research by the ACRP resources. The International Civil Aviation Organization (ICAO) has developed a calculator to assess $CO_2$ emissions from air travel. The ICAO Calculator allows passengers to estimate the emissions attributed to their air travel in a simple way and requires only a limited amount of information from the user (ICAO 2019). The ICAO Calculator allows passengers to estimate emissions attributed to their air travel in a simple manner, requiring a limited amount of information from the user (ICAO 2019).

APPENDIX C

# Examples of Emissions and Technology Roadmaps

Table C-1 provides examples of technology roadmaps that can be used to achieve zero- or low-emissions targets in a future year.

**Table C-1. Examples of emissions roadmaps.**

| Roadmap/Plan | Sector | Target | Technology Priorities | Time Horizon | Reference |
|---|---|---|---|---|---|
| **Vancouver International Airport Carbon Reduction Roadmap** | Airport | Carbon neutral by 2020 and carbon free in 2050. | Renewable natural gas, green electricity, conservation. | 2020-2050 | YVR (2020) |
| **SFO Airport's Roadmap to Zero Carbon** | Airport | Achieve carbon neutrality and reduce GHG emissions by 50%, from a 1990 baseline, by 2021; achieve recognition at the ACA Level 3+ (carbon neutrality) level by 2021. | Renewable fuels, ZEV fleets, and a new Heat Recovery Chiller Plant. | 2016-2021 | SFO (2018) |
| **IATA Technology Roadmap** | Aviation | Global aviation carbon emissions: an average improvement in fuel efficiency of 1.5% per year from 2009 to 2020; a cap on net aviation $CO_2$ emissions from 2020 (carbon neutral growth); a reduction in net $CO_2$ emissions of 50% by 2050 relative to 2005 levels. | Fuel-efficient airframe and engine technologies. | 2013-2050 | IATA (2013) |
| **Getting to Zero: A Pathway to a Carbon Neutral Seattle** | City | Become a carbon neutral city by 2050. | Cleaner fuels, energy efficiency. | 2011-2050 | Lazarus et al. (2011) |
| **Zero Carbon Australia Stationary Energy Plan** | Stationary Energy | 100% stationary energy from renewable energy sources by 2020. | Renewables (combining solar thermal + wind) - Centralized energy grid via solar thermal. | 2010-2020 | Wright and Hearps (2010) |
| **Wind Water Solar** | 139 countries, all 50 states, many cities | Transition all primary energy sources to renewables and electrify all end uses by 2050. | Wind, hydro-electric, solar, tidal. Electrification of all end uses. | Today to 2050 | Jacobson et al. (2018) |
| **United Kingdom Road to Zero Strategy** | Automobile industry | End the sale of new conventional petrol and diesel cars and vans by 2040, with the expectation that the majority of new cars and vans sold will be 100% zero emission and that all new cars and vans will have significant zero emission capability. | Battery-electric vehicles and hydrogen fuel cell electric vehicles. | 2018-2040 | UK (2018) |

APPENDIX D

# Emissions Reduction and Reporting Programs

Voluntary emissions reduction programs allow businesses, colleges and universities, cities, countries, airports, and others to collectively join forces to reduce emissions and gain recognition. These programs include pledges in which an organization publicly states an emissions goal to reach at a future date and accreditation programs that certify an organization meets the criteria of a given emissions level.

To date, nine countries and one province have pledged to eliminate economy-wide emissions in the coming decades, while other countries have targeted specific sectors or end uses. A growing number of cities—such as those in the C40 Cities Coalition and the Carbon Neutral City Alliance—have announced carbon neutrality targets for 2050 (CNCA 2020). Hundreds of college campuses have committed to eliminating emissions, and architecture firms and other actors in the building sector have committed to carbon neutral buildings by 2030. The business community is also taking action by adopting "science-based targets" that encourage companies to phase out all GHG emissions by January 1, 2050. Table D-1 highlights key voluntary emissions reduction programs, organized by sector.

**Table D-1. Voluntary emissions reduction milestones and programs.**

| Sector | Milestones | Number of Commitments *(as of January 2021)* |
|---|---|---|
| **Airports** | • 2008: ACA program are established by Airport Council International (ACA 2018a).<br>• 2012: Stockholm-Arlanda is considered the first airport to have achieved carbon neutrality (AB 2012).<br>• 2015: As part of the United Nations Climate Change Conference, COP21, 50 European airports pledged to be carbon neutral by 2030. By 2020, the number had grown to 211 airports (ACI 2020).<br>• 2020: ACA program adds Level 4 and 4+. | Two airports have been recognized as ACA Level 4+, and over 300 airports have been recognized at any ACA level. 211 European airports have made the 2030 carbon neutrality pledge (ACI 2020). |
| **Buildings** | • 2006: The American Institute of Architects establishes the 2030 Challenge (Architecture2030 2018). | 175 architecture firms and several local governments have joined (Architecture2030 2018). |
| **Businesses** | • 1999: Carbon Neutral Certification (Carbon Neutral Network) established *(since discontinued)*.<br>• 2000: Shaklee Corporation is considered the first Climate Neutral certified business in April 2000.<br>• 2015: Science-Based Targets Initiative established (partnership between CDP, United Nations Global Compact, World Resources Institute, World Wide Fund for Nature, We Mean Business Coalition) (CDP et al. 2020). | 553 companies have joined the Science-Based Targets. |
| **Cities** | • 2014: Carbon Neutral Cities Alliance (Urban Sustainability Directors Network) (CNCA 2020). | 22 cities are part of the Carbon Neutral Cities Alliance (CNCA 2020). |
| **Colleges and Universities** | • 2006: American College and University Presidents' Climate Commitment (Second Nature and The Association for the Advancement of Sustainability in Higher Education).<br>• 2007: College of the Atlantic in Maine becomes the first American school to achieve carbon neutrality (Gray 2018). | |
| **Countries** | • 2017: Bhutan is considered the world's first carbon negative country, due to its carbon sinks (CAT 2017). | More than 110 nations have committed to carbon neutrality (United Nations 2020). |
| **Any Sector** | • 2001: Greenhouse Gas Protocol (GHGP) established by World Resources Institute and World Business Council for Sustainable Development.<br>• 2006: International Organization for Standardization (ISO) establishes ISO 14064, standards for GHG accounting and verification (ISO 2006). | |

APPENDIX E

# Piloting the Implementation of the Guidebook

This guidebook was developed in two phases: a pre-publication version and a final published version. The pre-publication draft version of this guidebook, *ACRP Research Report 220: Guidebook for Developing a Zero- or Low-Emissions Roadmap at Airports,* was written over an 18-month period. Once the original draft was complete, the guidebook was posted for public access on the ACRP website.

This guidebook is intended to give airport staff best practices, tools, examples, and resources needed to develop a zero- or low-emissions roadmap for their own airports. To evaluate the effectiveness and utility of this guidebook, the research team helped two airports, Eugene Airport and Detroit Metropolitan Wayne County Airport, in a pilot implementation of the guidebook. This collaboration allowed the research team to gain valuable insights to revise the guidebook and inform how ACRP could maximize the implementation of future products. The underlying objective of piloting airport utilization of the guidebook was to evaluate the ways that it could be improved so other airports can successfully craft and implement a zero- or low-emissions roadmap of their own.

### Pilot Airports

**Eugene Airport (EUG)** is a municipally owned, small hub airport in Eugene, Oregon. In 2014, the City of Eugene adopted the Climate Recovery Ordinance, which set a goal that all city-owned facilities and city operations—including the airport—would be carbon neutral by 2020. This goal was achieved this year using both carbon mitigation and offset strategies. Airport staff, however, were not closely involved. Eugene Airport has recently updated its environmental sustainability plan and, at the time of ACRP pilot solicitation requests, was looking for assistance in developing an airport-specific zero- or low-emissions roadmap, outside the city's carbon neutrality efforts.

**Detroit Metropolitan Airport (DTW)** has shown a consistent commitment to reducing emissions. The airport entered the Airport Carbon Accreditation (ACA) program in 2016 and recently achieved ACA Level Three status. DTW is exploring how to advance to carbon neutrality and is evaluating how the airport can achieve this objective in an environment with cold winters and deep snow. A significant portion of Michigan's electricity comes from natural gas- and coal-fired generation sources.

## Guidebook Implementation Process

The research team led the pilot implementation project between November 2019 and November 2020. The initial months involved identifying candidates for the pilots. Once the airports were selected, the research team worked remotely with key airport staff and their internal stakeholder teams to provide technical and logistical assistance to implement the guidebook and develop the airport's own zero- or low-emissions roadmaps. The sections below describe the key steps of the project.

## Selection of Pilot Airports

To identify the pilot airports, the research team conducted outreach to airports across the country to learn more about their current status regarding zero- or low-emissions planning and to gauge interest in participating in the pilot implementation effort. The research team scheduled phone calls with airport staff to explain the pilot, the potential benefits for participating, and how the project could help ACRP improve its guidebook. The research team received letters of interest from four airports. Ultimately, the ACRP Project Panel selected Eugene Airport and Detroit Metropolitan Wayne County Airport.

## Airport-Specific Plans

An initial step was to develop an airport-specific plan that described the sequence of milestones between initiating and finalizing the pilot. To gain a baseline understanding about each airport's unique needs, the research team conducted an online survey. The survey asked the airports about the larger emissions-related ecosystem at the airport, including legislative, regulatory, and planning actions as well as recent goals.

DTW noted it had many ideas about how to achieve its carbon goals from different divisions in the airport's operations. DTW needed support facilitating the various goals and team members to develop a coherent plan and give some direction to the group.

EUG noted its small size and limited resources were a barrier to pursuing expansive sustainability work. EUG needed the support of the pilot for educational and process guiding purposes to help navigate the GHG inventory and develop emissions reductions strategies.

The research team followed the airport-specific plan over the course of the pilot implementation efforts.

## Roadmap Implementation Timeline for EUG and DTW

After developing the airport-specific plan, the research team initiated the pilots in separate formal kickoff meetings with EUG and DTW in March 2020. The research team provided remote technical assistance to EUG and DTW airport staff beginning in March 2020 and continuing through October 2020 and November 2020, respectively. The research team facilitated over 15 individual meetings each with EUG staff and DTW staff. These included technical briefings on critical planning topics, facilitation support to key meetings of internal airport implementation teams, and ad hoc calls and support to the primary airport contacts developing the roadmaps.

## Support Provided

The research team provided technical guidance and assistance to DTW and EUG in the following ways:

- Assisted the airport in developing an agenda and presentation slides for each meeting;
- Assisted in the development of roadmap resources;

- Assisted in specifying roles for airport staff and other stakeholders in roadmap implementation;
- Contributed to research for roadmap development;
- Conducted emissions inventory in ACERT (EUG only);
- Presented on technical topics to inform airport staff and other stakeholders on available funding mechanisms, emissions tracking and metrics, electric aircraft, sustainable aviation fuels, GHG inventory strategies, future aviation developments, and options for emissions-reductions strategies;
- Connected the airport to peer airports and facilitated lessons-learned meetings;
- Supported developing the structure and layout of the roadmap;
- Provided a technical review of airport roadmap draft;
- Provided technical language and writing support for roadmap draft; and
- Assisted with editing and graphic design of roadmap.

## Pilot Outcomes

Both DTW and EUG produced draft zero- or low-emissions roadmaps with specific, ready-to-use emissions-reductions implementation strategies and tracking metrics as a result of this pilot implementation. Both airports now have a step-by-step action plan with carbon reduction goals outlined that they can immediately implement and return to over time. The cover pages of the draft roadmaps developed by EUG and DTW are presented in Figure E-1. Interested parties may contact representatives from the sustainability departments of each airport for more information about the roadmaps.

## Feedback on and Revisions to the Guidebook

The pilot airports, EUG and DTW, provided feedback on the content of the guidebook throughout the pilot effort and after its conclusion. The airports provided verbal feedback during the regular support calls and written feedback in various emails, documents, and surveys shared with the research team. The airport pilots helped validate the scope of the guidebook. Overall, the airports agreed with the chapter structure and topics covered in the guidebook. Both verbally and in writing, EUG and DTW indicated that the technical assistance provided in the guidebook and throughout the pilot process were of great value. In


*Figure E-1. Draft roadmaps developed by EUG and DTW.*

addition to the overall feedback on the guidebook, the reviewers provided chapter-specific suggestions for revisions. This feedback helped the research team to identify areas of the guidebook for improvement and has been incorporated in the final and published version of the guidebook.

## Other Key Takeaways from the Pilot Implementation

**The pilot implementation process for the guidebook was mutually beneficial.** For both for the airports participating in the pilot and the research team, the process was instructive in improving the guidebook. While undertaking roadmap implementation, both pilot airports conducted thorough reviews of the guidebook and identified key chapters that were of unique focus to them. These areas of focus—such as conducting a GHG emissions inventory using the ACERT tool or identifying the ways that pursuing a zero-emissions roadmap benefits the airport—helped illuminate the best ways for the research team to provide technical assistance. The research team planned technical presentations aimed at helping the pilot airports understand key aspects of zero emissions planning or technical concepts.

**Regularly held meetings were a critical aspect of the pilot.** The research team held regular check-in meetings with the airports throughout the pilot implementation process, which proved essential for ensuring progress. These meetings provided consistent checkpoints for evaluating progress and introduced collaboration on important topics. The research team presented technical information on topics such as an outline for the roadmaps, considerations for airport GHG reduction strategies, carbon reduction-related language and terminology, goal setting, and funding mechanisms.

**For the research team, the input provided by the pilot airports was instrumental in refining and finalizing the guidebook.** During and after the pilot implementation phase, the airports pointed to specific chapters of the guidebook that could be made more digestible, accessible, applicable, and useful. In addition, assisting airports in the process of implementing the guidebook helped shed light on how other airports might use the guidebook, specifically the elements that could be of most and least value to other guidebook users. Both pilot airports provided helpful feedback, written and verbal, which informed the entire roadmap implementation process and specified areas for guidebook revisions that may have otherwise been overlooked. One of the pilot airports suggested that ACRP could revisit this project in 5 to 10 years to evaluate how airports have been able to apply the guidebook to their own roadmaps. The pilot implementation process also revealed how different the needs can be for airports, depending on region, size, climate and weather conditions, amount of resources already devoted for environmental sustainability projects, and other characteristics.

## Level of Effort

The research team collected data on the level of effort required from airport staff and from the supporting research team over the duration of the pilot implementation process (i.e., for an 8-month period). This information is intended to provide a rough order of magnitude estimate of the potential amount of work that might be required by other airports in developing a zero- or low-emissions roadmap of their own. The level of consultant support that may be needed to develop a zero- or low-emissions roadmap could be anticipated to be in the range of 150 to 400 hours (depending on specific airport needs). One of the pilot airports estimated that their airport spent about 420 labor hours to conduct relevant research, coordinate with colleagues, attend meetings, and write and review the roadmap.

## Conclusions

This ACRP pilot implementation effort resulted in benefits to both the participating airports and to ACRP. By working directly with two airports that were applying the guidebook to develop their own zero- or low-emissions roadmaps, the research team gained significant insight about ways to improve the guidebook. The takeaways from interacting with end users of ACRP products can be applied to other ACRP implementation products in the future. Additionally, the guidebook piloting process reinforced the need to directly involve stakeholders in the evaluation of ACRP implementation products as they are being developed.

These airport stakeholders are effective communicators about how ACRP products can help address their needs and how these products can be improved before they are finalized. The research team proposes that ACRP continue to incorporate this model into its research processes. The feedback from Eugene Airport and Detroit Metropolitan Wayne County Airport during the pilot process was instrumental in improving and finalizing this *Guidebook for Developing a Zero- or Low-Emissions Roadmap at Airports* and providing lessons that can be applied to other ACRP research projects.

*Abbreviations and acronyms used without definitions in TRB publications:*

| | |
|---|---|
| A4A | Airlines for America |
| AAAE | American Association of Airport Executives |
| AASHO | American Association of State Highway Officials |
| AASHTO | American Association of State Highway and Transportation Officials |
| ACI–NA | Airports Council International–North America |
| ACRP | Airport Cooperative Research Program |
| ADA | Americans with Disabilities Act |
| APTA | American Public Transportation Association |
| ASCE | American Society of Civil Engineers |
| ASME | American Society of Mechanical Engineers |
| ASTM | American Society for Testing and Materials |
| ATA | American Trucking Associations |
| CTAA | Community Transportation Association of America |
| CTBSSP | Commercial Truck and Bus Safety Synthesis Program |
| DHS | Department of Homeland Security |
| DOE | Department of Energy |
| EPA | Environmental Protection Agency |
| FAA | Federal Aviation Administration |
| FAST | Fixing America's Surface Transportation Act (2015) |
| FHWA | Federal Highway Administration |
| FMCSA | Federal Motor Carrier Safety Administration |
| FRA | Federal Railroad Administration |
| FTA | Federal Transit Administration |
| GHSA | Governors Highway Safety Association |
| HMCRP | Hazardous Materials Cooperative Research Program |
| IEEE | Institute of Electrical and Electronics Engineers |
| ISTEA | Intermodal Surface Transportation Efficiency Act of 1991 |
| ITE | Institute of Transportation Engineers |
| MAP-21 | Moving Ahead for Progress in the 21st Century Act (2012) |
| NASA | National Aeronautics and Space Administration |
| NASAO | National Association of State Aviation Officials |
| NCFRP | National Cooperative Freight Research Program |
| NCHRP | National Cooperative Highway Research Program |
| NHTSA | National Highway Traffic Safety Administration |
| NTSB | National Transportation Safety Board |
| PHMSA | Pipeline and Hazardous Materials Safety Administration |
| RITA | Research and Innovative Technology Administration |
| SAE | Society of Automotive Engineers |
| SAFETEA-LU | Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005) |
| TCRP | Transit Cooperative Research Program |
| TDC | Transit Development Corporation |
| TEA-21 | Transportation Equity Act for the 21st Century (1998) |
| TRB | Transportation Research Board |
| TSA | Transportation Security Administration |
| U.S. DOT | United States Department of Transportation |

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